University of Stuttgart
Institute of Human Factors and Technology Management IAT

Fraunhofer

CITY LAB KOCHI, INDIA

CLIMATE RISK AND RESILIENCE ASSESSMENT

FULL VERSION AND RESULTS

Photo: Alain Dubois

MORGENSTADT GLOBAL SMART CITIES INITIATIVE
GLOBAL APPROACH – LOCAL SOLUTIONS

Morgenstadt City of the Future

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

CONTENTS

1 INTRODUCTION 2
2 FRAMEWORK AND DEFINITIONS 3
3 CLIMATE RISKS AND VULNERABILITIES 5
3.1 SEA LEVEL RISE AND COASTAL EROSION 5
3.2 HEAVY RAINFALL AND STORMWATER 7
3.3 WATER SCARCITY 10
3.4 TEMPERATURE RISE AND URBAN HEAT ISLANDS 12
3.5 CHANGE IN BIOLOGICAL SYSTEM 15
4 CLIMATE CHANGE ADAPTION MEASURES 17
5 OVERARCHING INSIGHTS AND SUGGESTIONS 21
6 KOCHI CITY LAB – CONTRIBUTIONS TO CLIMATE RISK ADAPTION 23
7 ANNEX 26
7.1 CLIMATE RISK AND RESILIENCE EXPERT SURVEY RESPONSE VALUES 26
7.2 INVOLVED EXPERTS 30
8 PUBLICATION BIBLIOGRAPHY 31
9 AUTHORS 34

1 INTRODUCTION

Climate change represents one of the major global challenges of this time with immense impacts on urban life. Due to population growth and rapid urbanization it is projected that 70% of the world's population will be living in cities by 2050 (United Nations 2015). The United Nations further acknowledge the wide scope and scale of climate change impacts, ranging from shifting seasons and more extreme weather events to rising sea levels which increase the risk of flooding and inundation. These risks are especially threatening in places with low adaptation capacity and a lack of essential infrastructure and services (Aziz et al. 2018).

To combat climate change and to accelerate actions and investments required for a more sustainable and resilient future, several international policy frameworks have been developed over the years. At the United Nations Framework Convention on Climate Change Conference of the Parties (COP21) held in Paris in December 2015 for instance, cities were recognized as key actors in both mitigation and adaptation to climate change, encompassing low emission developments and increased urban resilience (United Nations-Framework Convention on Climate Change 2016).

India is very vulnerable to climate change, notably due to the melting of Himalayan glaciers and the change in Monsoon patterns. India has fostered The National Action Plan on Climate Change (NPCC) on 30 June 2008, which outlines a number of steps to simultaneously advance India's development and climate change related objectives (Ministry of Environment, Forest and Climate Change 2008). Furthermore, the country ratified the Paris agreement on the 2nd October 2016, almost exactly a year after it submitted its climate pledge or Nationally Determined Contribution (NDC) for the Paris climate talks.

The Morgenstadt Global Smart Cities Initiative (MGI) is an international development co-operation 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), Piura (Peru) and Saltillo (Mexico), 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 Kochi, 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 sea level rise and coastal erosion, heavy rainfall and stormwater, water scarcity, temperature rise and urban heat islands, as well as the change in the biological system. It also assessed the adaptation measures that the city of Kochi has already implemented to deal with these risks. 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 resilience towards the discussed climate risks.

2 FRAMEWORK AND DEFINITIONS

In the following, the results of a climate change risk and resilience assessment for Kochi 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 1 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 and frequency: measure of how likely and often a hazard will occur.

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

Exposure (temporal and 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 of 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): "anticipating 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).

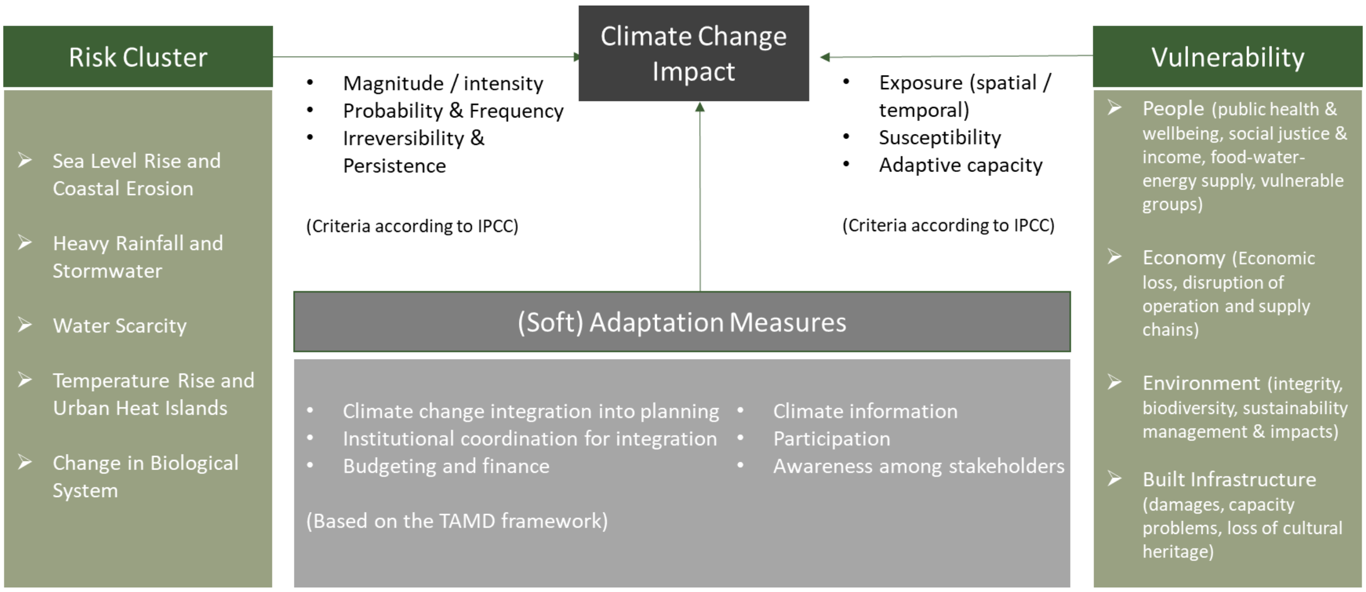

Figure 1: Risk and Resilience Assessment Framework

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 later was conducted by ten local and City Lab experts, to better incorporate local knowledge and on-site findings on risk clusters and vulnerabilities. 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 Kochi.

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 Kochi was synthesized from the overall City Lab assessment, as well as from two risk and resilience related expert interviews conducted in July 2020. A list of survey participants and interviewees, as well as a full table with all survey results can be found in the Annex.

3 CLIMATE RISKS AND VULNERABILITIES

3.1 SEA LEVEL RISE AND COASTAL EROSION

The city of Kochi lies barely 5 meters above the sea level and has a coastline of 48 kilometers. It is embedded in a complex network of rivers, tidal creeks and backwaters, due to which Kochi has been regularly exposed to natural disasters like floods, cyclones, droughts and landslides. Over the past decade, sea level rise has, among others, led to growing concerns on climate change impacts (Aziz et al. 2018). While in the period of 1949 – 1998 no significant change has been observed in the mean sea level near Kochi, the predicted 0.9 m of global sea level rise by 2100 would have very high impacts on the city. Researchers predict that Kochi will be facing around 0.6 meters of sea level rise until 2050 (ORNL & CUSAT 2003). Expected impacts include an increased risk of flooding and coastal erosion, which would predominantly affect areas of touristic interest and densely populated central areas. According to the DC-DMA, around 10 % of the houses are at risk. Furthermore, increased saltwater intrusion in both surface and groundwater sources threatens the natural freshwater reservoirs. Figure 2 shows the expert evaluation following the on-site assessment in 2020.

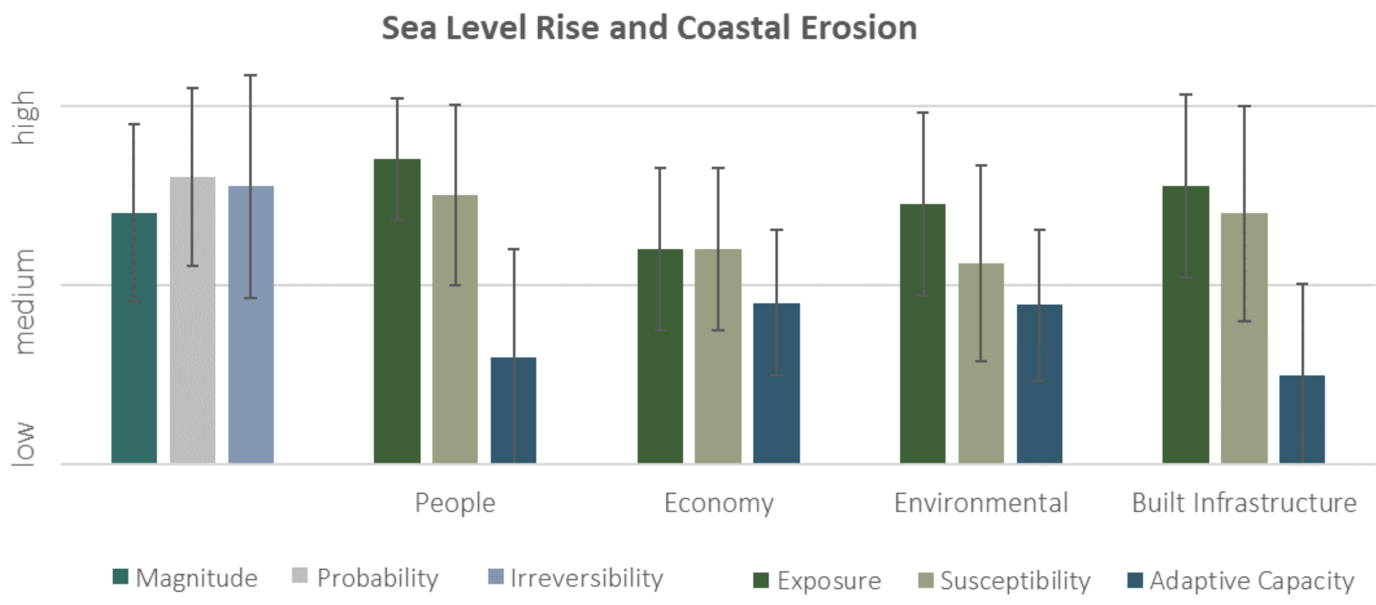

Figure 2: Expert evaluation for the risk cluster "sea level rise and coastal erosion" for the city of Kochi, including general risk factors and the vulnerability of the social, economic, environmental and built systems in the city. Survey results with 10 participants from different local institutions and City Lab on-site experts. Standard deviation shown as black bars.

Even though it was claimed that the western coast of India is less vulnerable to sea level rise, the geographic location of the city of Kochi results in 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.

In accordance to the literature, submergence of land, increased flood events, saltwater intrusion, and a disruption of human activities were named as major impacts by the experts. Fast urbanization, land reclamation, and intense dredging activities, which create a loss of natural water retaining structures, could amplify these impacts. On the other side, the existing channels and aquifers in the region are seen as an opportunity to partly absorb and cope with increasing water levels, if they are well maintained and not congested. Furthermore, it has been highlighted, that past flood events have shown that a fast and consequent response of government and civil society is crucial to succeed in minimalizing losses and compensating damages.

It was indicated that many citizens live in the CRZ or in other flood-prone areas. Due to the canal system, also the city center and areas that are not directly located at the coast are exposed to the impacts of rising water levels. Furthermore, a loss of potable water sources and the salinization of soil have been named as direct risks for the people.

Opinions regarding the adaptive capacity of the people with regards to sea level rise and coastal erosion varied strongly from high to low.

Regarding the economic system, it is expected that many services and operations may be interrupted at least temporarily due to the named impacts (especially flooding), as most of the economic activities are being carried out at the coast. However, not all industries will be affected equally. Named examples for especially vulnerable sectors were tourism (e.g., when attractions as the Fort Kochi are not accessible anymore), Kochi Port, and the fishery industry. The finance sector, which also constitutes a strong pillar of Kochi’s economy, is seen as less vulnerable. Accordingly, the adaptive capacity varies from sector to sector as well.

In terms of local environment and ecosystem, some losses to the native flora and fauna are expected. Named as especially vulnerable were the local marshlands, which will be impacted by an increase in salinity and flooded areas. Furthermore, the population dynamics of aquatic life could be significantly affected by changing properties of water bodies (such as salinity and temperature). Local sustainability projects, such as AMRUT, would be important for conservation and adaptation. However, a lack of adequate funds lessens their success (currently the primary funding source is the national rejuvenation scheme).

3.2 HEAVY RAINFALL AND STORMWATER

According to Köppen Geiger classification, Kochi's climate is classified as Am - tropical monsoon climate, implying frequent rainfall especially during the monsoon season (Kottek and Rubel 2010). On the website of the Indian Meteorological Department, the average annual rainfall amounts to 3140.93 mm/year with the typical precipitation patterns and monthly means shown in Figure 3. Future projections of Indian summer monsoon rainfall suggest a reduction in the frequency of light rainfall and an increase in high to extreme rainfall events. Furthermore, a higher inter-annual variability is predicted (Jayasankar et al. 2015). The highest rainfall events for the period of one month recorded for Kochi in the last five years were 314.85mm, 293.49mm, 569.0mm, 1183.50mm and 919.60mm for the years 2016-2020 respectively (World Weather Online 2020).

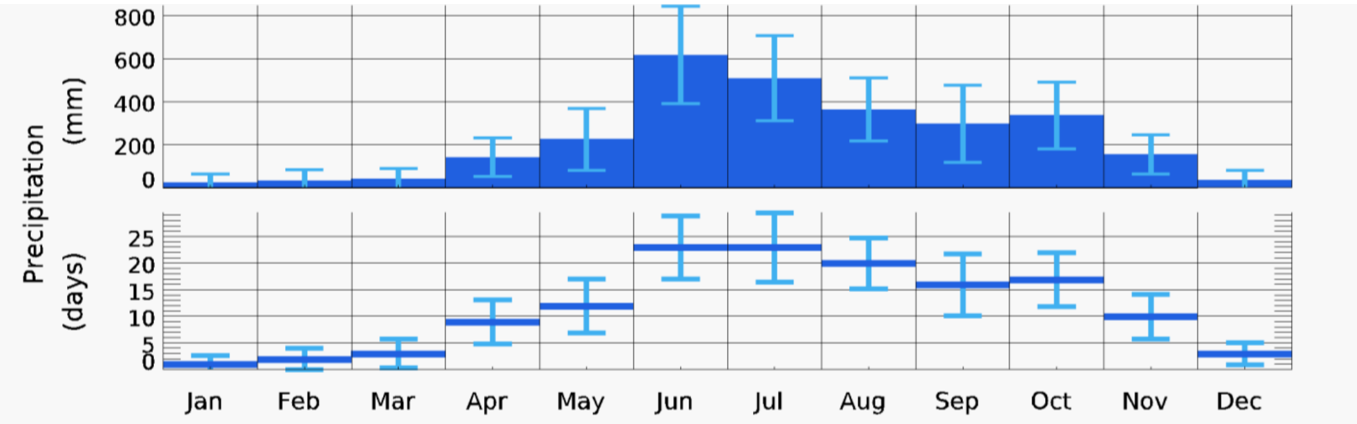

Figure 3: Precipitation amount (mm) and range of monthly means in two thirds of the years. Below: number of precipitation days per months and two-thirds variation in the city of Kochi. Graphs taken from meteoblue; Cochin/Willingdon 9.95°N / 76.27°E (3m asl); measurements of at least 10 years (meteoblue 2020).

In the years 2018 and 2019, not only Kochi, but almost the entire state of Kerala, has been facing severe flood events due to the changes in rainfall patterns (see Figure 4). The Chief Minister of Kerala, tweeted on August 17, 2018, on the flood situation in Kerala:

"[…] Kerala is facing its worst flood in 100 years. Eighty dams opened, 324 lives lost, and 223139 people are in about 1500+ relief camps".

Figure 4: Kerala floods and landslides amid heavy rains in 2018 (Source: Down to Earth August 16, 2018)

During heavy rainfall events, surface water runoff exceeds the amount of water that infiltrates into the ground, thereby contributing to floods, erosion, water logging, and a more rapid siltation of waterways. This phenomena is worsened in highly urbanized areas where impermeable paving further reduces the areas infiltration capacity (Aziz et al. 2018). Figure 5 presents the expert evaluation for the risk cluster heavy rainfall and storm water.

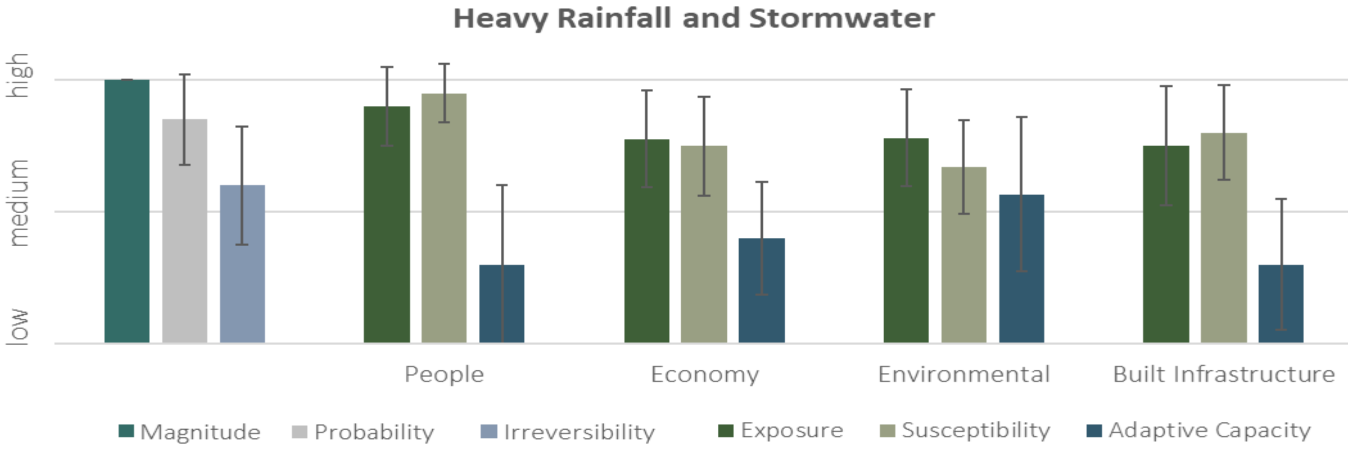

Figure 5: Expert evaluation for the risk cluster "heavy rainfall and stormwater" for the city of Kochi, including general risk factors and the vulnerability of the social, economic, environmental and built systems in the city. Survey results with 10 participants from different local institutions and city lab on-site experts. Standard deviation shown as black bars.

The change in precipitation patterns is perceived as a very relevant risk for the city of Kochi. Across all risk and vulnerability factors, it was ranked the highest by the experts. Most experts referred to the more frequent and heavy rainfalls of the past years, which have led to many fatalities and damages, mainly due to flooding and landslides. Waterlogging and flood events have been mentioned to occur with almost every rainfall. Here, the blocking of canals with solid waste (see Figure 6) has been identified as intensifying factor that obstructs the storm water flow and worsens flooding.

Figure 6: Waterlogging Kochi in October 2019 (Source: The NEWS Minute April 17, 2020)

In terms of socio-economic vulnerability, it was stated that especially low-income areas and informal settlements are at risk. Furthermore, past floods have disrupted water supply and transport facilities, which disabled the movement of people and commodities. During the heavy rainfall events in 2018, Kochi airport had to close for over 10 days (Majumder 2018). The dense population and the limited availability of space were identified as major barriers to implement further adaptation measures.

In terms of natural ecosystems, the adaptive capacity of the natural surroundings has been rated as generally rather high. However, it has been stated that recent developments and encroachments have led to a loss of natural space and thus a lower capacity of local ecosystems to address rainfall and flood events. As resulting flash floods have received a lot of attention in the media, it is hoped that future planning and management of urban projects will take the environment and the potential of nature-based solutions to contribute to climate adaptation more strongly into account. Lastly, the spread of polluted storm water has been seen as a risk to local wildlife and biodiversity.

Kochi’s infrastructure was built to take the Monsoon climate and occasional heavy rains into account. It was mentioned that the canals in the city were supposed to offer some degree of buffer. The improvement of proper drainage and new facilities for rainwater harvesting and use were suggested as important measures to enhance capacities and lower its vulnerability. In 2018 many buildings have been destroyed because of flooding and landslides.

3.3 WATER SCARCITY

As described in the previous sections, the general water availability in Kochi is good, due to natural water resources (rivers and groundwater) and annual rainfall volumes. However, a decrease in rainfall or shift in precipitation patterns is associated with a greater likelihood of shortages of drinking water, increased water pollution due to less dilution and flushing, more extensive saltwater intrusion, and possibly increased costs of electricity if hydropower potentials are affected (ORNL & CUSAT 2003). These shortages would become even more relevant, when the demand of water and electric power rises due to higher temperatures, e.g., due to increased rates of water evaporation or an increasing use of electric cooling devices. With a performance of wastewater treatment of about 4 % (Government of Kerala 2015), and no real infrastructure for rainwater harvesting, the option of water reuse is not yet explored. For the future, such approaches and solutions could significantly help to prevent water scarcity issues. Figure 7 presents the expert evaluation on risk factors and vulnerabilities regarding water scarcity.

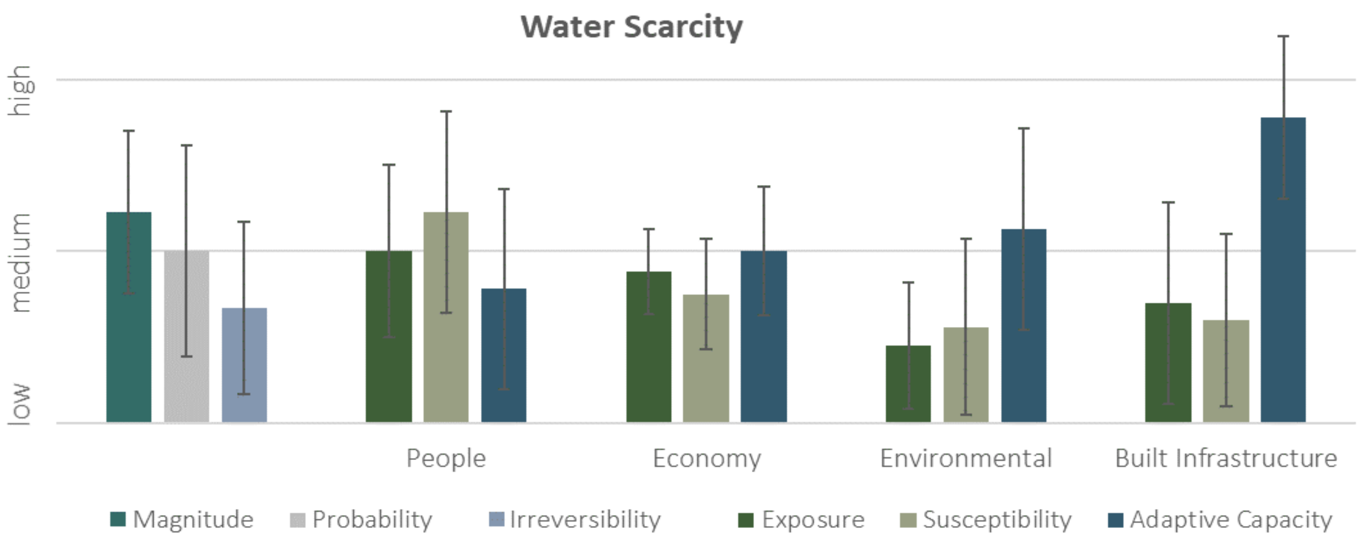

Figure 7: Expert evaluation for the risk cluster "water scarcity" for the city of Kochi, including general risk factors and the vulnerability of the social, economic, environmental and built systems in the city. Survey results with 10 participants from different local institutions and city lab on-site experts. Standard deviation shown as black bars.

In accordance to the statements above, the risk of and associated vulnerabilities with regards to water scarcity are rated as low to medium (lowest rating in the overall survey). It has repeatedly been mentioned that there is sufficient water available in terms of quantity. However, qualitatively high drinking water is not accessible to all citizens, a situation that could become worse under the pressures of climate change. Concerns have also been put forward regarding potential impacts and disruptions to the water supply system, i.e., if potable groundwater sources become saline, or if pollution from the canals enters and contaminates drinking water reservoirs due to lower ground water tables. Additionally, the poor conditions and reach of pipe infrastructure and the supplementary supply by trucks were mentioned as vulnerable points in the supply system. Artificial recharge of ground waters and rainwater harvesting solutions were suggested as means to improve the situation. A lack of legislative and political initiative, and long public discussions (as in the case of establishing wastewater treatment plants) were named as expected main barriers to the realization of such measures.

3.4 TEMPERATURE RISE AND URBAN HEAT ISLANDS

Figure 8 shows the observed minimum and maximum temperatures in the city of Kochi over the course of the year. As characteristic for the climate zone, temperatures are rather high with little fluctuations throughout the seasons (meteoblue 2020). In terms of temperature increase, former studies have seen a rise in average temperature of around 1°C in the city of Kochi over the last 50 years. Considering a continuous development, it was predicted that the temperature would increase by another degree Celsius in the next 50 years from then (ORNL & CUSAT 2003). More recent studies for all of India confirm the monotonous temperature increase during the 21st century. According to these, the projected future (2070–2099) will see a rise in temperature by 3.99°C (±1.27°C) or 1.19°C (±0.797°C) with respect to the reference period from 1961 to 1990. The variations depend on the used scenario and the underlying assumptions for the calculations, still in both cases a clear future increase of temperature is predicted (Jayasankar et al. 2015).

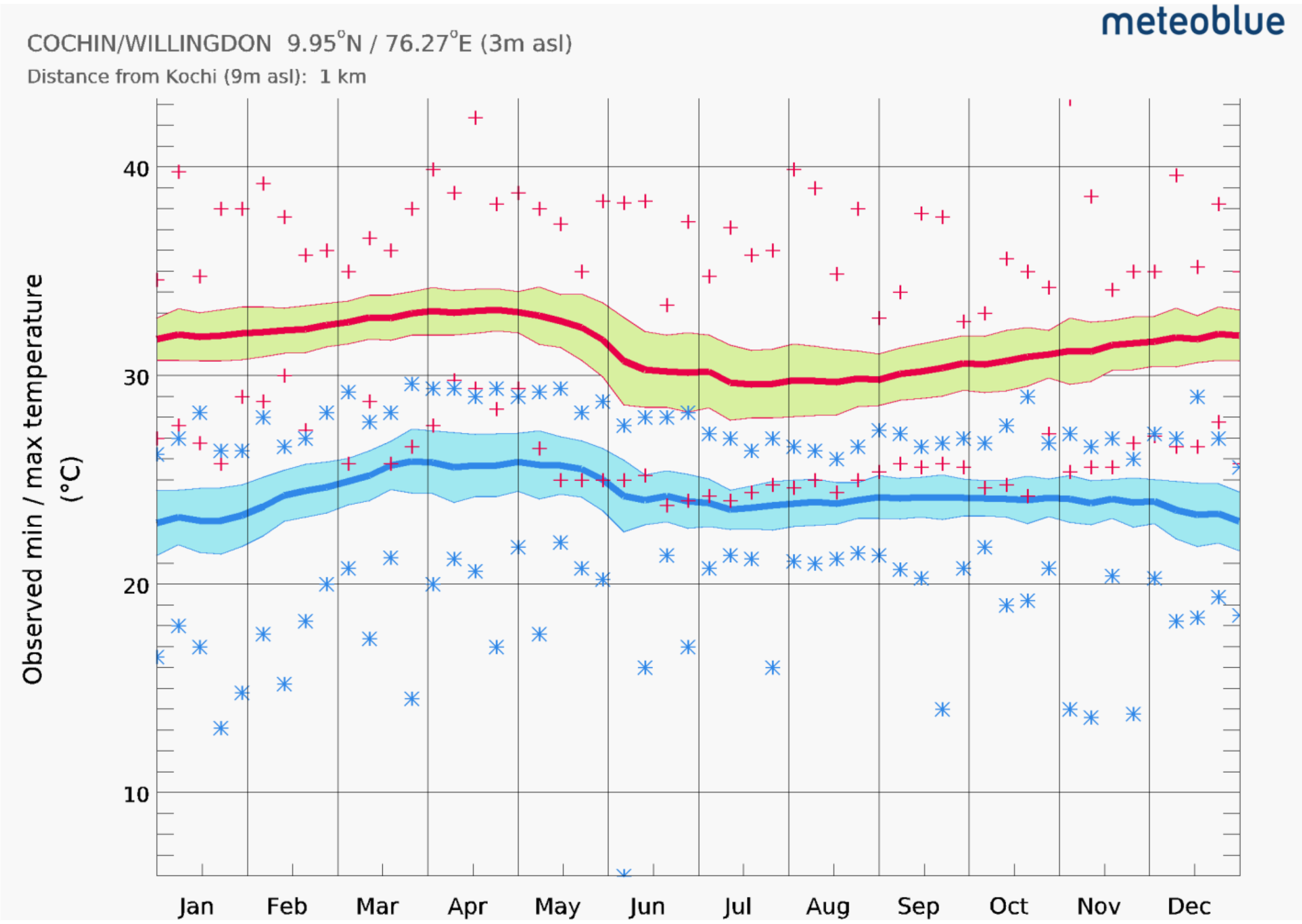

*Figure 8: Observed maximum (red) and minimum (blue) temperatures in the city of Kochi. Extreme values are represented by + and * characters. Two thirds of observed temperatures lie within the colored temperature range. Graph taken from meteoblue; Cochin/Willingdon 9.95°N / 76.27°E (3m asl); measurements of at least 10 years (meteoblue 2020)*

A major contributor to the high temperatures in cities is the urban heat island effect (UHI), which is a predominant climate risk in urban areas. Amongst others, it is a result of lacking vegetation and surface moisture, extensive paved surfaces, the canyon effect of buildings, heat-trapping pollutants in the atmosphere, as well as human activities in urban space. In 2014, a study in the city of Kochi determined UHI intensities of up to 4.6°C (Thomas et al. 2014). A more recent study in other major Indian cities resulted in even higher UHI intensities of 10.5–14 °C during the summer periods, correlating with the intensity of built-up areas (Sultana and Satyanarayana 2020). Altogether high and increased temperatures in cities may lead to climate-related health issues, especially on vulnerable groups, as well as a higher demand in water and electricity (e.g., for cooling and refrigeration devices). Figure 9 presents the expert evaluation with regards to temperature rise and urban heat islands.

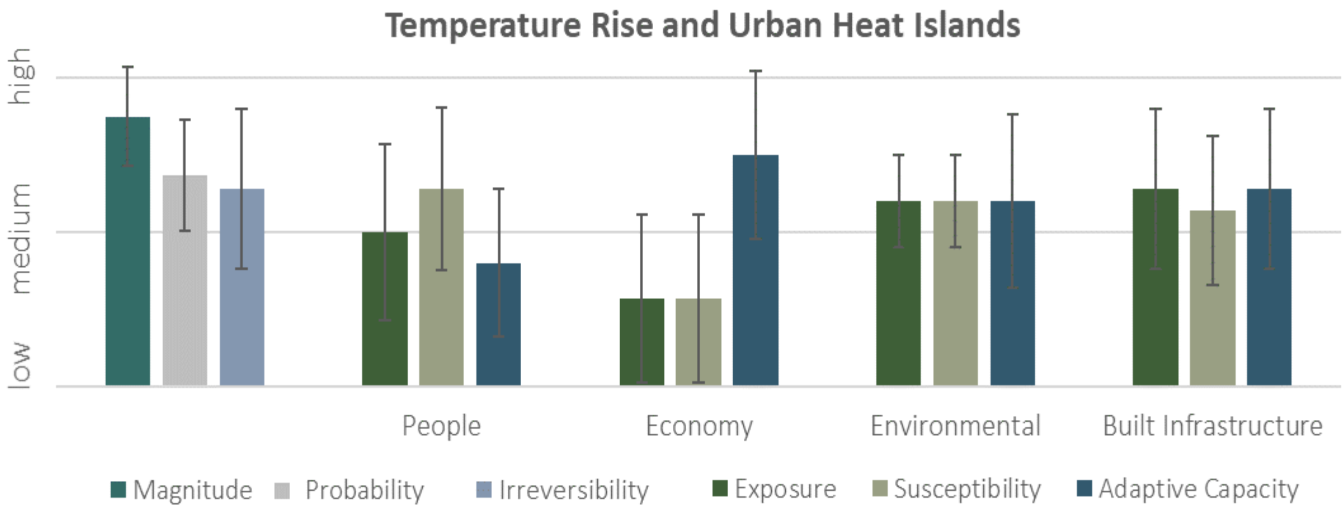

Figure 9: Expert evaluation for the risk cluster "temperature rise and urban heat islands" for the city of Kochi, including general risk factors and the vulnerability of the social, economic, environmental and built systems in the city. Survey results with 10 participants from different local institutions and City Lab on-site experts. Standard deviation shown as black bars.

In general, the effects of rising temperatures and UHIs are perceived as important risk for the city of Kochi, especially due to the fact that the city center is already quite densely built-up, blocking natural ventilation and cooling structures such as the lagoons and waterbodies. While the vulnerability of the local economy towards higher temperatures is evaluated as rather low, the emphasis is placed on the vulnerability and the low adaptive capacity of the citizens. Effects on the local environment were not that well-known (50 % response rate).

As important measure against the UHI several experts referred to the green infrastructure in the city, especially in terms of the large number of existing trees. Moreover, the tree planting support by the Kochi Municipality within the "cities4forest" program was named as a currently running adaptation measure (see **Figure 10**). Emphasis was put on the fact that, next to conserving existing and planting new trees, a proper management and maintenance will be key to ensure a long lasting and sustainable contribution of green infrastructure to temperature reduction. Furthermore, close work with local communities and vulnerable groups could help building knowledge and strengthening the citizen's resilience and adaptive capacity to heat.

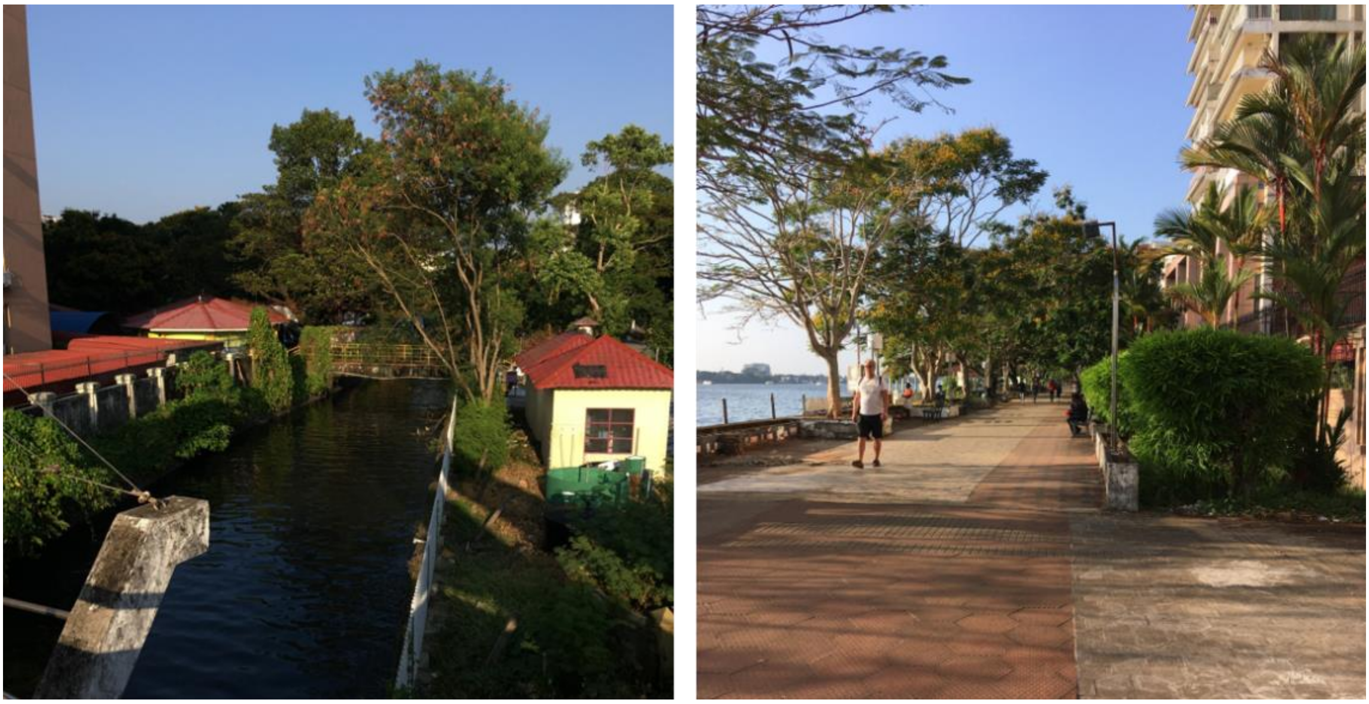

Figure 10: Blue-Green Infrastructure in Kochi (© Fraunhofer IBP)

3.5 CHANGE IN BIOLOGICAL SYSTEM

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 thereby include agriculture and crop growth (Ashalatha et al. 2012; Pande et al. 2010), marine life and fisheries (Vivekanandan 2011; Badjeck et al. 2010), or biodiversity in general (Sharma and Bazaz 2012; Rani et al. 2016). Whereas actual impacts in these areas are still debated and remain uncertain, the combination of increased flooding, water stagnation, waste accumulation and warm temperatures in Kochi were found to provide excellent breeding grounds for disease organisms and the disease vectors (mosquitoes, flies, and rodents) which can transmit the diseases to humans. This situation already contributes to disease outbreaks, and such impacts might become more frequent and severe. Figure 11 summarizes the expert evaluation with regards to changes in the biological system.

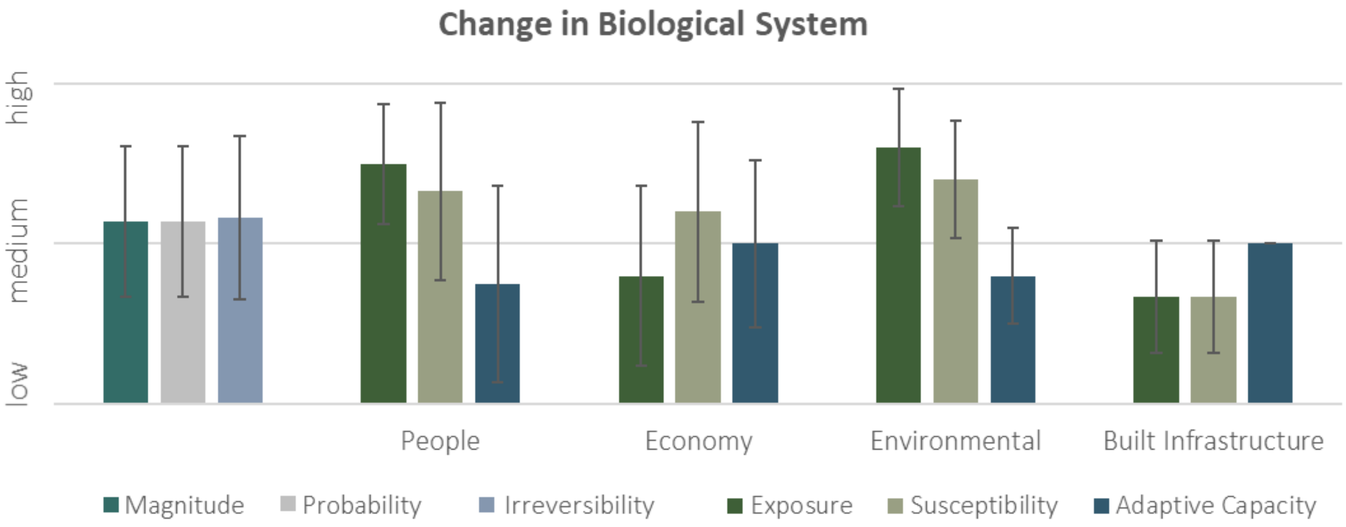

Figure 11: Expert evaluation for the risk cluster "change in biological system" for the city of Kochi, including general risk factors and the vulnerability of the social, economic, environmental and built systems in the city. Survey results with 10 participants from different local institutions and City Lab on-site experts. Standard deviation shown as black bars.

Generally, response rates indicated a bigger uncertainty and lack of knowledge on the climate change risks and vulnerabilities with regards to changes in the biological system in Kochi, which correlates with the debate in scientific literature. The main concern, which was raised by multiple experts, related to potential negative impacts on aquatic and marine life, especially fish and shellfish populations which are the primary source of income for the Kochi fishing industry. A decrease would therefore negatively impact the local environment, the livelihood of fishermen and citizens, as well as commercial fishery and economy. Next to this issue, tourism and nature conservation were named as most impacted areas. Lastly, the mapping of food systems and availability in risk situations (from different climate-related impacts) was named as important area of action for city authorities, e.g. through supporting more local and resilient production and innovative solutions.

4 CLIMATE CHANGE ADAPTION MEASURES

In the light of the aforementioned risks, climate change adaptation needs to play a more prominent role in future 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 Kochi with regards to six distinct indicator areas from the TAMP framework based on the City Lab data collection and the resilience interviews. The result suggests many opportunities to further deepen and improve existing climate governance and adaptation measures, of which some of the most prominent will be outlined in the following two sections.

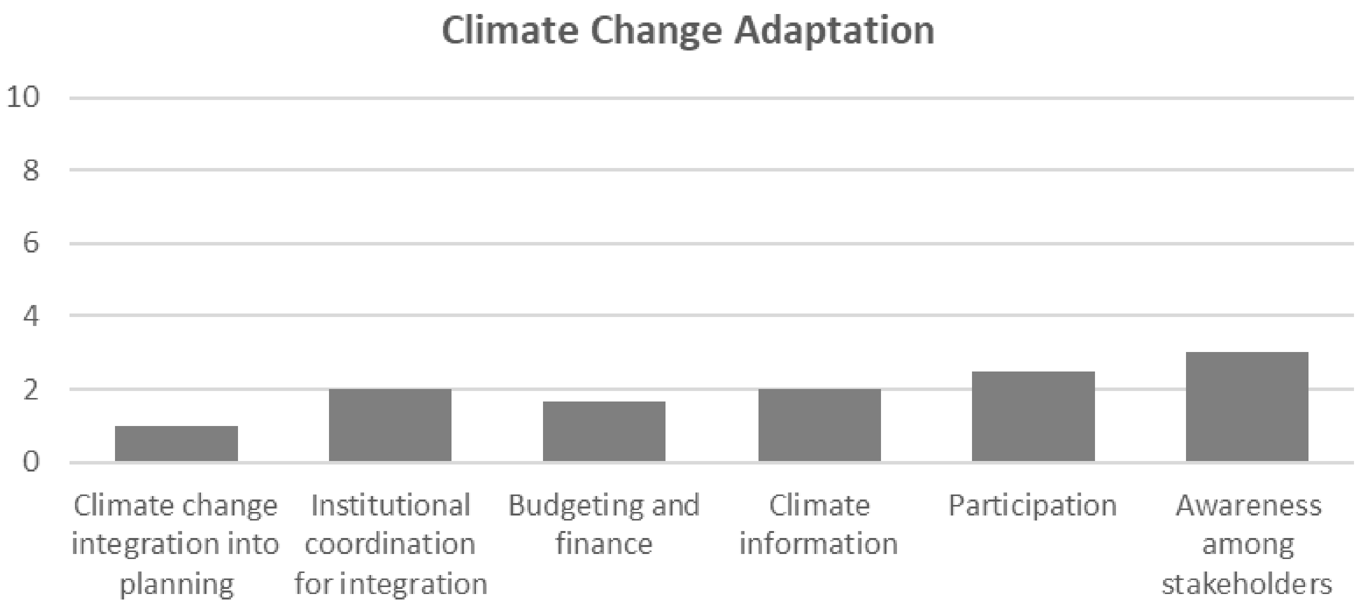

Figure 12: Climate change adaptation assessment according to the TAMP framework (iied 2014). Each indicator consists of 3 to 5 questions which amount to a maximum score of 10.

Climate Change Integration into Planning

High-level strategies on climate change in general exist on national and state level (e.g. National Action Plan on Climate Change and Kerala state action plan) (Government of Kerala 2014; Government of India).

As part of the latter, it is stated that "for every Grama Sabaha, District Panchayat, Municipality and Corporation, an area specific climate resilient plan must be developed. This plan would identify adaptation needs at the local level that focuses on reducing local level climate risk and vulnerabilities and ways of increasing resilience." (Government of Kerala 2014), p.138). Still, due to weak enforcement and lack of priority, there has been no city-level plans or policies on climate change in Kochi itself. Several activities and projects, as a resilience plan, which has been elaborated together with ICLEI, or the Climate Smart Cities project with the GIZ, have not been incorporated in official urban planning and decision-making.

While individual conservation and adaptation projects do exist (e.g., at the Vembanad Lake System), they address single hotspots and are not realized in a coordinated approach. Furthermore, there are individual risk monitoring activities being carried out by different organizations, but no routine assessment and evaluation. The need for structural and binding plans, especially in the areas of water drainage, storm water management and urban heat islands, was perceived as crucial for the city's future.

Institutional Coordination for Integration

Up until now, the main responsibility regarding climate change issues was mostly covered by the Disaster Management Authority in many states, including Kerala. Due to this allocation, actions and responses have so far been very much focused on reaction and disaster management (ex post) rather than prevention and adaptation (ex ante). So far, there is no body or person responsible for sustainability or resilience issues and it was stated that such entities might not be very powerful and play more of an informative role, due to the rather hierarchical and top-down planning culture in India (unless they would be given power by the government).

In Kochi specifically, KMC is the statutory body responsible for climate and planning issues and the current work on the Master Plan Kochi is being undertaken by the Town Planning Department. To better represent climate change adaptation in this master plan and other strategic decision-making processes, more cross-sectoral cooperation was suggested - with KMC being in the lead and GCDA, Town Planning Department, State Planning Department, as well as the Disaster Management Authority being involved.

Furthermore, it was mentioned that this work should also include the 13 local self-governments, which exist in Kochi. In general, it was perceived as most efficient if there would be a strong and binding policy on climate change on the state level, which could be translated into localized actions in Kochi – an approach that would require a close and well-functioning collaboration between the different governance levels.

Budgeting and Finance

In terms of available financing and funding sources, it was mentioned that access to funds is very limited. Some available budgets for pilot measures that address climate change were named on the national level (NAFCC), cities would first approach the state level for financial support. There has been no funding program mentioned to rollout and support the mainstreaming of climate change actions or to cover the costs for thorough risk screening and assessment.

Climate Information

Regarding the availability of climate information, existing data sources at state level were mentioned, whereas for the Panchayat (village) or the Municipal level, significant data gaps were noted. Examples for missing data were information on sea level rise (constant monitoring), water quality and pollution sources and local level emissions. An attempt to develop updated and actionable flood maps to identify and better manage risk areas is still not available in 2020 due to a low prioritization by the government. Furthermore, it has been stated that the concern that some climate-related information might lower real estate values of certain places did play a role and hindered some monitoring and sharing processes of data.

In terms of further information, there is some data available from scientific literature and work with international and foreign organizations. Additionally, Kochi University does work and research on climate and atmospheric science. However, the usefulness is often limited, as it is not transferred into a more actionable format. Furthermore, local and traditional knowledge does exist (e.g., on community level), which however is often not respected in decision-making.

As an example, local communities have raised their concerns regarding the water flows in the area of the current airport (which was built on formerly declared farmland) in the planning process. These being ignored, the airport has been built in a flood-prone area, which has led to major disruptions during the latest flooding events. Generally, climate information and risk assessments results are not used in current urban planning processes.

Regarding the sharing of data, it was mentioned that the IMD regularly sends warnings on upcoming weather events. Still, there is no early warning system within the city that directly targets and reaches citizens and local communities (e.g., by sending alerts to mobile phones of at-risk groups).

Participation

Three participation vehicles have been named in the interviews and data collection. Firstly, the ward committee, which has been selected within the smart city program and consists of stakeholders from different institutions (the main areas and modes of operation however have not been identified). Secondly, with regards to affected communities, the Kochi Flood App has been launched in 2019 as part of the Climate Smart Cities Programme in collaboration with the GIZ. The app enables citizens to post pictures of affected and flooded areas, which will then be forwarded to city officials that investigate and solve the causes. The users of the app will be informed on the status and the solution of the uploaded cases (Shibu BS 2019). As of now, no information on the usage and impact of the app in risk management has been reported.

Lastly, it has been observed that there are activist groups which work and lobby for certain climate-related topics, such as the effects on biodiversity and the protection of migratory birds. Still, on an overarching level, planning is perceived as rather top-down where the city level itself has not much power and the community level is not really considered in planning and implementation.

Awareness Among Stakeholders

According to the interviews, general awareness levels on climate risks and impacts (especially on flooding and heat stress) are rather high amongst the citizens. In addition to a well-educated population, the flood events of 2018 have led to an increased awareness on climate impacts and new realities. For instance, a drop in demand for waterfront properties has been noted in the following years. On the other side, the knowledge on how to act and improve local resilience towards climate impacts within daily life was perceived as rather low. Institutions such as C-HED are working together with vulnerable communities to increase disaster preparedness and bottom-up adaptation, but still more streamlined education and capacity building work is seen as important. According to DC-DMA estimates for the district and own expert computation, it is estimated that only about 0.17 % of the district population is trained in emergency response. In terms of available funding for awareness raising, it was pointed out that government funding is limited to government institutions, such as for example Kudumbashree. As municipal funds for such activities are also limited, lots of work in that area is still being conducted on a voluntary basis. This becomes difficult, especially when larger actions with high coordination efforts have to be conducted, e.g., in disaster relief.

5 OVERARCHING INSIGHTS AND SUGGESTIONS

Following the assessments, a few conclusions could be drawn, especially with regards to main priorities, potential levers and low hanging fruits for future climate change adaptation.

Firstly, a clear priority and need for improved water management and flood mitigation has emerged from literature research, surveys and interviews. Suggested actions and assets for a better adaptation include

- the development of actionable and publicly available flood maps and consistent city level data
- the set-up of citizen-friendly early warning systems
- the establishment of decentralized water management structures including rainwater harvesting, storage, treatment and reuse
- an improved implementation, use and maintenance of nature-based solutions
- the cleaning and management of the existing canal infrastructure.

These actions could help in strengthening anticipation and prevention work, instead of focusing on disaster management and relief.

Secondly, proper risk assessment and monitoring schemes are needed to build a basis for knowledge-based decision-making. For this, data gaps have to be identified and tackled and relevant data updated and routinely measured. Existing local institutions and scientific bodies could be engaged in such an undertaking, as also the Oceanographic Department and the University of Kochi, the Earth Science Institute in Trivandrum, the Indian Meteorology Department, etc. Also, engagement with NGOs and community level organizations could help in gathering and monitoring data on the local level. Sea level rise, rainfall and temperature patterns, urban heat islands and cooling spots, water quality and freshwater resources, species composition, green infrastructure coverage and quality, demographic patterns, as well as vulnerable areas and infrastructure could be important areas for monitoring and data collection. Streamlining information and enabling accessibility for the public helps increasing awareness, adaptive capacity, and transparency.

Thirdly, high-level policy work is needed to create a legally binding planning document with clear regulations and instructions. Potential elements of such a strategy could include climate sensitive zoning plans, stricter building and construction regulations, water drainage requirements, and mandatory climate risk assessments for larger urban development projects. The policies should be built on existing knowledge and climate-related studies and become the basis for a more strategic and holistic approach to addressing climate risks. As such, it has to be elaborated in an interdisciplinary and cross-departmental manner and at the right governance level to enforce implementation and compliance, as well as to ensure the allocation of sufficient funds.

In addition, Kochi should further extend the work on the community level, to leverage on community-based adaptation. Collaboration with existing organizations from civil society sector, NGOs as Thanal, neighborhood associations, religious groups, etc. could form a basis to enable bottom-up communication, capacity building, consul-tation and support.

Strong and resilient communities can enhance the adaptive capacity of people, limit the magnitude of climate change impacts, and enable efficient emergency response.

Furthermore, well-informed citizens are more likely to raise their voices and put pressure on the government to place critical topics on the political agenda. Studies in different Indian cities have shown success in addressing climate-related risks through community-based adaptation strategies on grassroots level, when being supported by local governments (Ravinder Dhiman et al. 2019).

Further points that have been raised are the potential of engaging in national and international city-to-city exchanges and research projects to share and learn from best practices in dealing with climate change, putting more emphasis on prevention and adaptation work, and further engagement in political discussions to advocate for the importance of climate action on all governance levels.

6 KOCHI CITY LAB – CONTRIBUTIONS TO CLIMATE RISK ADAPTION

As part of the MGI Kochi City Lab, a roadmap has been developed which includes concrete project ideas that could support the city in its climate-friendly future development (Mohr, M. et al. 2020). Whilst most of these projects target specific challenges in the focus sectors of the City Lab – namely water, buildings and built environment and energy – they also hold a great potential to help enhancing climate resilience. Figure 13 shows the links between the developed project ideas and the risk clusters as described above.

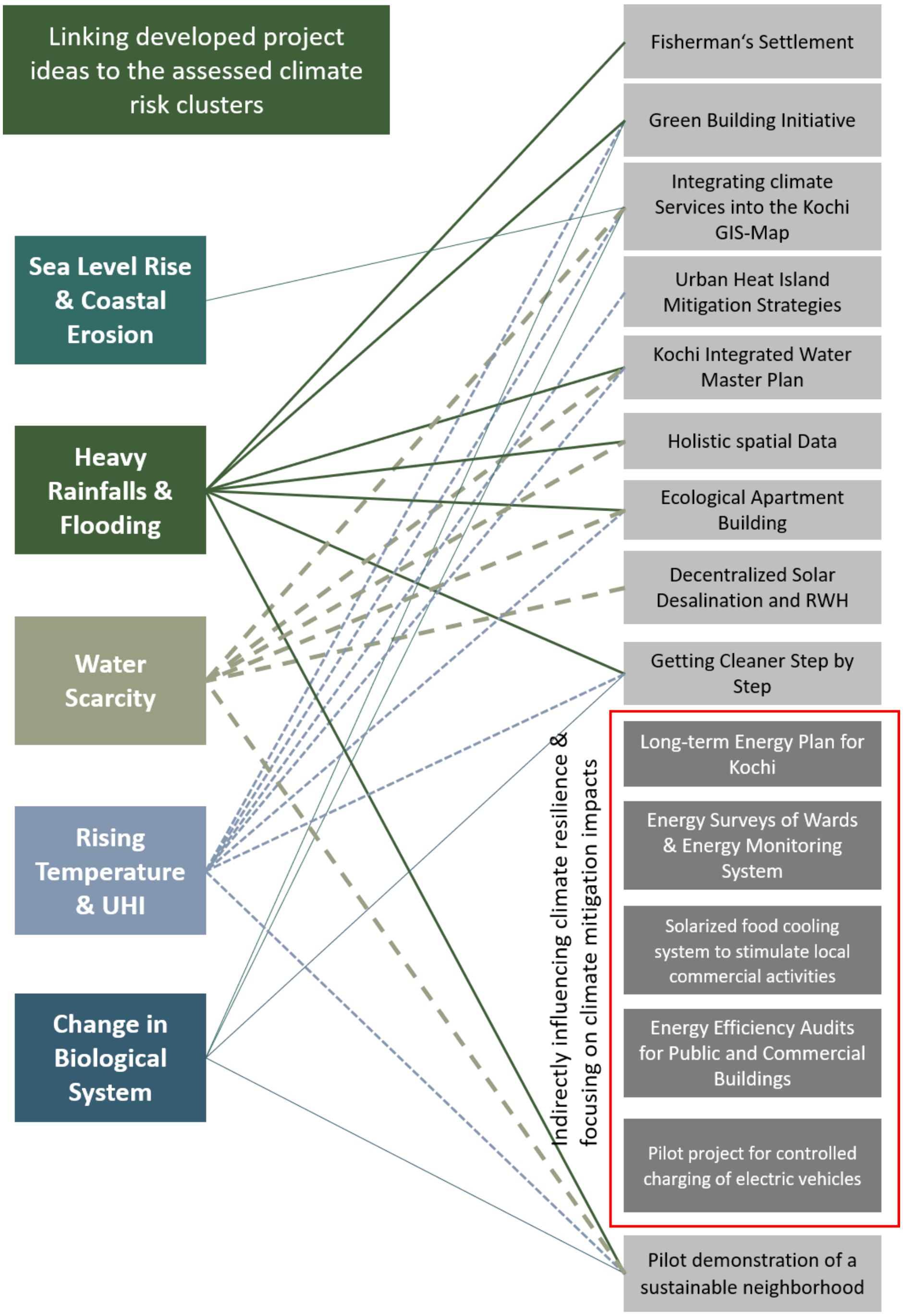

Figure 13: Linking project development ideas to the assessed climate risk clusters

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 TAMP 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 a first guiding support for future project planning, implementation, and monitoring in the city of Kochi. 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.

Indicator Cluster	Indicator	Unit of Measure	Description	Source
Sea level rise & Coastal Erosion	Reduction in water logging events	Number of events/year	Lesser frequency of water logging events in case of moderate rainfall than previous year	MGI Indicators
	Coastal erosion and accretion	km	Length of (newly) protected and defended coastline	DEDUCE(DEDUCE June 1st, 2007)
Heavy Rainfalls & Flooding	Flood peak height		Increase flowrate (peak flow) reduction due to a given rain event, thanks to the project intervention. The peak flow is the maximum value of the flowrate 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 flowrate, 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.	Nature 4 Cities (Nature4Cities 2017)
	Areas exposed to flooding	ha	Updated flood maps and monitoring data	MAES (European Commission 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% (The aim of this indicator is to know if the project intervention increased soil permeability, which impacts on flood reduction)	Singapore Index(Chan et al. 2014)

Indicator Cluster	Indicator	Unit of Measure	Description	Source
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	CITY keys (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 / %	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		Structural and functional connectivity of green spaces and habitats	UnaLab (Wendling et al. 2019)
			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)

Table 1: Overview of indicators to be used in the monitoring and performance evaluation of certain climate change risk categories (exemplary compilation).

7 ANNEX

7.1 CLIMATE RISK AND RESILIENCE EXPERT SURVEY RESPONSE VALUES

Sea Level Rise and Coastal Erosion

RISK factors	Magnitude/ intensity	Probability /Frequency	Irreversibility/ Persistence
Expert rating	2,40	2,60	2,55
Mean deviation	0,66	0,66	0,83
Response rate	100 %	100 %	90 %

Vulnerability		People	Economy	Environmental	Built infrastructure
Expert rating	Exposure	2,70	2,20	2,45	2,55
	Susceptibility	2,50	2,20	2,12	2,40
	Adaptive Capacity	1,60	1,90	1,89	1,50
Mean deviation	Exposure	0,45	0,60	0,68	0,68
	Susceptibility	0,67	0,60	0,73	0,80
	Adaptive Capacity	0,80	0,54	0,56	0,68
Response rate	Exposure	100 %	100 %	90 %	90 %
	Susceptibility	100 %	100 %	90 %	100 %
	Adaptive Capacity	100 %	100 %	90 %	100 %

Heavy Rainfall and Stormwater

RISK factors	Magnitude/ intensity	Probability /Frequency	Irreversibility/ Persistence
Expert rating	3,00	2,70	2,20
Mean deviation	0,00	0,46	0,60
Response rate	100 %	100 %	90 %

Vulnerability		People	Economy	Environmental	Built infrastructure
Expert rating	Exposure	2,80	2,55	2,56	2,50
	Susceptibility	2,90	2,50	2,34	2,60
	Adaptive Capacity	1,60	1,80	2,13	1,60
Mean deviation	Exposure	0,40	0,49	0,49	0,60
	Susceptibility	0,30	0,50	0,47	0,48
	Adaptive Capacity	0,80	0,57	0,78	0,66
Response rate	Exposure	100 %	90 %	90 %	100 %
	Susceptibility	100 %	90 %	90 %	100 %
	Adaptive Capacity	100 %	90 %	80 %	100 %

Water Scarcity

RISK factors	Magnitude/ intensity	Probability /Frequency	Irreversibility/ Persistence
Expert rating	2,23	2,00	1,67
Mean deviation	0,63	0,82	0,67
Response rate	90 %	90 %	90 %

Vulnerability		People	Economy	Environmental	Built infrastructure
Expert rating	Exposure	2,00	1,88	1,45	1,70
	Susceptibility	2,23	1,75	1,56	1,60
	Adaptive Capacity	1,78	2,00	2,13	2,78
Mean deviation	Exposure	0,67	0,33	0,49	0,78
	Susceptibility	0,78	0,43	0,68	0,67

	Adaptive Capacity	0,78	0,50	0,78	0,63
Response rate	Exposure	90 %	80 %	90 %	100 %
	Susceptibility	90 %	80 %	90 %	100 %
	Adaptive Capacity	90 %	80 %	80 %	90 %

Temperature Rise and Urban Heat Islands

RISK factors	Magnitude/ intensity	Probability /Frequency	Irreversibility/ Persistence
Expert rating	2,75	2,37	2,28
Mean deviation	0,43	0,48	0,69
Response rate	80 %	80 %	70 %

Vulnerability		People	Economy	Environmental	Built infrastructure
Expert rating	Exposure	2,00	1,57	2,20	2,28
	Susceptibility	2,28	1,57	2,20	2,14
	Adaptive Capacity	1,80	2,50	2,20	2,28
Mean deviation	Exposure	0,76	0,73	0,40	0,69
	Susceptibility	0,70	0,73	0,40	0,64
	Adaptive Capacity	0,64	0,73	0,75	0,69
Response rate	Exposure	70 %	70 %	50 %	70 %
	Susceptibility	70 %	70 %	50 %	70 %
	Adaptive Capacity	70 %	70 %	50 %	70 %

Change in Biological System

RISK factors	Magnitude/ intensity	Probability /Frequency	Irreversibility/ Persistence
Expert rating	2,14	2,14	2,16
Mean deviation	0,63	0,63	0,68
Response rate	77,77 %	77,77 %	66,66 %

Vulnerability		People	Economy	Environmental	Built infrastructure
Expert rating	Exposure	2,50	1,80	2,60	1,67
	Susceptibility	2,33	2,20	2,40	1,67
	Adaptive Capacity	1,75	2,00	1,80	2,00
Mean deviation	Exposure	0,50	0,75	0,49	0,47
	Susceptibility	0,74	0,75	0,49	0,47
	Adaptive Capacity	0,82	0,70	0,40	0,00
Response rate	Exposure	66,66 %	55,55 %	62,50 %	37,50 %
	Susceptibility	66,66 %	55,55 %	62,50 %	37,50 %
	Adaptive Capacity	44,44 %	44,44 %	62,50 %	37,50 %

7.2 INVOLVED EXPERTS

Climate Risk and Resilience Assessment Interviews:

1	Dr.	Rajan Chedambath	C-HED Centre for heritage, environment and development
2	Mr.	Jayakumar	THANAL

Climate Risk and Resilience Expert Survey Participants:

	Participants	Organization
Dr.	Markus Schwegler	University of Stuttgart (IAT)
Ms.	Ernesta Maciulyte	University of Stuttgart (IAT)
Ms.	Amruta Jayawant	University of Stuttgart (IAT)
Dr.-Ing.	Marius Mohr	Fraunhofer IGB
Mr.	Marc Beckett	Fraunhofer IGB
Ms.	Sabine Giglmeier	Fraunhofer IBP
Ms.	Anitha Mohandas	CSML
Ms.	Anna Brittas	NIUA
	Anonymous	India
	Anonymous	India

8 PUBLICATION BIBLIOGRAPHY

Ashalatha, K. V.; Munisamy Gopinath; Bhat, A. R. S. (2012): Impact of climate change on rainfed agriculture in India: a case study of Dharwad. In *International Journal of Environmental Science and Development* 3 (4), pp. 368–371.

Aziz, Zeba; Ray, Indro; Paul, Sandeep (2018): The role of waterways in promoting urban resilience: The case of Kochi City Working Paper. Available online at https://www.econstor.eu/handle/10419/203693.

Badjeck, Marie-Caroline; Allison, Edward H.; Halls, Ashley S.; Dulvy, Nicholas K. (2010): Impacts of climate variability and change on fishery-based livelihoods. In *Marine Policy* 34 (3), pp. 375–383. DOI: 10.1016/j.marpol.2009.08.007.

Bosch, p. et al. (2017a): CITYkeys list of City indicators. With assistance of CITY keys. Available online at https://nws.eurocities.eu/MediaShell/media/CITYkeyslistofcityindicators.pdf, checked on 3/15/2021.

Bosch, p. et al. (2017b): CITYkeys list of project indicators. With assistance of CITY keys. Available online at https://nws.eurocities.eu/MediaShell/media/CITYkeyslistofprojectindicators.pdf, checked on 3/15/2021.

Chan, L.; Hillel, O.; Elmqvist, T.; Werner, P.; Holman, N.; Mader, A.; Calcaterra, E. (2014): User's Manual on the Singapore Index on Cities' Biodiversity (also known as the City Biodiversity Index). Singapore: National Parks Board, Singapore. Available online at https://www.cbd.int/authorities/doc/Singapore-Index-User-Manual-20140730-en.pdf.

DEDUCE (June 1st, 2007). Using Indicators to measure Sustainable Development at the European Coasts. Edited by DEDUCE Secretariat. Belgium, Brussels. Available online at http://www.vliz.be/projects/deduce/pdf-newsletter/deduce_3.pdf.

European Commission (2016): Mapping and Assessment of Ecosystems and their Services. 4th Report. With assistance of Urban ecosystems. Luxembourg. Available online at https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/102.pdf.

European Commission (2020): Adaptation to climate change. Available online at https://ec.europa.eu/clima/policies/adaptation_en, checked on 7/15/2020.

Government of India: National Action Plan on Climate Change. Available online at http://moef.gov.in/division/environment-divisions/climate-changecc-2/national-action-plan-on-climate-change/, checked on 7/20/2020.

Government of Kerala (2014): Kerala State Action Plan on Climate Change. Available online at https://envt.kerala.gov.in/wp-content/uploads/2019/10/Kerala-State-Action-Plan-on-Climate-Change-KSAPCC-2014-August.pdf.

Government of Kerala (2015): State Annual Action Plan (SAAP- 2015-16) Kerala. Atal Mission for Rejuvenation and Urban Transformation (AMRUT). Available online at http://www.corporationoftrivandrum.in/sites/default/files/SAAP-KERALA-2015-16.pdf, checked on 7/7/2020.

Hansen, R.; Rall, E.; Chapman, E.; Rolf, W.; Pauleit, S. (2017): Urban Green Infrastructure Planning. A guide for practitioners. Green Surge. Munich. Available online at https://www.e-pages.dk/ku/1340/html5/, checked on 4/9/2021.

IIED (2014): The Tracking Adaptation and Measuring Development (TAMD) framework. Available online at https://www.iied.org/tracking-adaptation-measuring-development-tamd-framework, updated on 10/28/2014, checked on 7/1/2020.

Jayasankar, C. B.; Surendran, Sajani; Rajendran, Kavirajan (2015): Robust signals of future projections of Indian summer monsoon rainfall by IPCC AR5 climate models: Role of seasonal cycle and interannual variability. In *Geophys. Res. Lett.* 42 (9), pp. 3513–3520. DOI: 10.1002/2015GL063659.

Kottek; Rubel (2010): World Map of Köppen-Geiger Climate Classification updated. Available online at http://koeppen-geiger.vu-wien.ac.at/, updated on 2010, checked on 7/9/2020.

Majumder, Soumyajit (2018): Kochi Airport, Closed Due To Heavy Flooding And Rain, To Reopen August 29. Edited by NDTV, updated on 8/22/2018, checked on 7/10/2020.

McCaffrey, S. (n.y.): WATER QUALITY PARAMETERS & INDICATORS. Waterwatch. Available online at https://sswm.info/sites/default/files/reference_attachments/MCCAFFREY%20ny%20Water%20Quality%20Parameters%20&%20Indicators.pdf.

meteoblue (2020): Climate observed Kochi. Kerala, India, 9.94°N 76.26°E, 9m asl. Available online at https://www.meteoblue.com/en/weather/historyclimate/climateobserved/kochi_india_1273874, checked on 7/9/2020.

Ministry of Environment, Forest and Climate Change (2008): NATIONAL ACTION PLAN ON CLIMATE CHANGE. Government of India. India. Available online at http://moef.gov.in/division/environment-divisions/climate-changecc-2/national-action-plan-on-climate-change/.

Mohr, M. et al. (2020): City Profile Kochi, India. The Full Technical Report of Comprehensive Analysis and Roadmap Definition for the City of Kochi. With assistance of Morgenstadt Global Initiative. Stuttgart.

Morgenstadt Global Smart Cities Initiative (2020). With assistance of University of Stuttgart. Available online at https://mgi-iki.com/, checked on 4/1/2021.

Nature4Cities (2017): D2.1 – System of integrated multi-scale and multithematic performance indicators for the assessment of urban challenges and NBS. Version 7. European Commission. Available online at https://9e99b973-33ae-43f5-b05a-fbba8e8b1314.filesusr.com/ugd/55d29d_3b17947e40034c168796bfc9a9117109.pdf.

Oppenheimer, M.; Campos, M.; Warren, R.; Birkmann, J.; Luber, G.; O'Neill, B.; Takahashi, K. (2014): Emergent risks and key vulnerabilities. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contributions on Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 1039–1099.

ORNL & CUSAT (2003): Possible vulnerabilities of Cochin, India, to climate change impacts and response strategies to increase resilience. Available online at https://agris.fao.org/agris-search/search.do?recordID=US201300092898.

Pande, S.; Desai, S.; Sharma, M. (2010): Impacts of climate change on rainfed crop diseases:current status and future research needs (National Symposium on Climate Change and Rainfed Agriculture). Available online at http://oar.icrisat.org/8308/.

Rani, V.; Sreelekshmi, S.; Asha, C. V.; Nandan, S. Bijoy (2016): Forest Structure and Community Composition of Cochin Mangroves, South-West Coast of India. Springer. Available online at https://link.springer.com/article/10.1007/s40011-016-0738-7, updated on 7/17/2020, checked on 7/17/2020.

Ravinder Dhiman; Renjith VishnuRadhan; T. I. Eldho; Arun Inamdar (2019): Flood risk and adaptation in Indian coastal cities: recent scenarios. In *Appl Water Sci* 9 (1), pp. 1–16. DOI: 10.1007/s13201-018-0881-9.

Sharma, K. S.; Bazaz, A. B. (2012): Sustainable Management of Biodiversity in the Context of Climate Change-Issues, Challenges and Response. In *Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci.* 82 (2), pp. 251–260. DOI: 10.1007/s40011-012-0095-0.

Shibu BS (2019): App soon to help tackle flooding in Kochi. Edited by The New Indian Express. Available online at https://www.newindianexpress.com/cities/kochi/2019/nov/13/app-soon-to-help-tackle-flooding-in-kochi-2060900.html, updated on 11/13/2019, checked on 7/15/2020.

Sultana, Sabiha; Satyanarayana, A. N. V. (2020): Impact of urbanisation on urban heat island intensity during summer and winter over Indian metropolitan cities. Springer. Available online at https://link.springer.com/article/10.1007/s10661-019-7692-9, updated on 7/13/2020, checked on 7/13/2020.

Thomas, George; Sherin, A. P.; Ansar, Shareekul; Zachariah, E. J. (2014): Analysis of Urban Heat Island in Kochi, India, Using a Modified Local Climate Zone Classification. In *Procedia Environmental Sciences* 21, pp. 3–13. DOI: 10.1016/j.proenv.2014.09.002.

United Nations (2015): World Population Prospects: 2015 Revision, checked on 1/14/2021.

United Nations-Framework Convention on Climate Change (2016): Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015. Part two: Action taken by the Conference of the Parties at its twenty-first session. Paris, checked on 3/15/2021.

Vivekanandan, E. (2011): Marine Fisheries Policy Brief-3; Climate change and Indian Marine Fisheries. In *CMFRI Special Publication* 105, pp. 1–97. Available online at http://eprints.cmfri.org.in/8440/.

Wendling, L.; Rinta-Hiiro, V.; Jermakka, J.; Fatima, Z.; Rüdenhausen, M.; Ascenso, A. et al. (2019): Performance and Impact Monitoring of Nature-Based Solutions. D3.1 Deliverable. Edited by UnaLab. Available online at https://unalab.eu/system/files/2020-02/d31-nbs-performance-and-impact-monitoring-report2020-02-17.pdf, checked on 1/21/2021.

World Weather Online (2020): World Weather Online. Available online at https://www.worldweatheronline.com/fort-cochin-weather-averages/kerala/in.aspx, checked on 9/9/2020.

9 AUTHORS

SOPHIE MOK
Researcher, Head of MGI Climate Assessment and Capacity Building
Fraunhofer Institute for Industrial Engineering IAO

DR. MARKUS SCHWEGLER
MGI Project Coordinator (2019-2021)
University of Stuttgart IAT

AMRUTA JAYAWANT
Research Assistant, Co-Lead City Lab Kochi
University of Stuttgart IAT

ANNA BRITTAS
Research Assistant
National Institute of
Urban Affairs, India