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Flood Vulnerability and the Quest for Resilience

Urban planning and development challenges in Matola, Mozambique

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ABSTRACT

Increased flood occurrence due to heavy rainfall associated with cyclones is recognized worldwide. Urban environments in developing countries, such as Matola in Mozambique, suffer greatly from the negative impacts of floods, and the 2000 floods were the most devastating, which pose great challenges to urban planners and local communities to promote flood resilience. This study investigates the challenges of promoting resilience to urban floods in Matola, Mozambique. The study focuses on how have flood hazards and risks been distributed in Matola and what mitigations and adaptations strategies, measures, and actions urban planners and communities used to promote flood resilience.

This is a case study based on a mixed quantitative and qualitative methodological approach. The study applies geoprocessing techniques to geospatial data in order to assess flood vulnerability and risk in Matola, in 2000, 2020, and 2040, using ArcGIS software. The main qualitative methods used are semi-structured interviews with urban planners and community members, and focus group discussions with community members, complemented by observations.

The findings indicate an increase in the extent of low-risk areas of flooding, and a decrease in the extent of medium/high-risk areas from 2000, through 2020, to 2040. However, there has been an increase in the number of inhabitants exposed to combined medium/high-risk areas of medium/high-hazard classes of flooding ranging from 0.5 m to approximately 5 m in depth, due to the increase in the horizontal expansion of land occupied by socio-economic infrastructure, particularly housing. The findings indicate that the mitigation actions during the 2000 floods focused on evacuating and accommodating people besieged by the floods. After the 2000 flood, adaptation measures were gradually implemented by supporting the return of residents to their homes, resettling households whose homes were permanently flooded in 2000, resettling residents of areas at high risk of flooding, and excavating drainage channels. The main strategy to promote flood resilience in Matola after the 2000 floods was capacity development through staff training, gradually hiring new staff by municipal administration, with different specializations essential for planning and managing land use and adaptation measures, and developing a new urban plan taking account of the flood hazards. The study reveals that during the 2000 floods, social capital, characterized by pre-existing strong social cohesion and mutual trust among community members, was a vital factor helping people come together to support and rescue community members besieged by floods. Community adaptation measures after the 2000 floods were the improvement and reconstruction of flood-destroyed houses, raising yard levels with fill, and adherence to the resettlement promoted by the municipality. The municipality's official collaboration network with communities through elected leaders favoured continuous connection between the parties and in organizing the gradual resettlement of residents who had lost their homes in the floods.

Keywords: Flood vulnerability, flood resilience, urban planning, community resilience, Matola

SAMMANFATTNING

Antalet översvämningar till följd av kraftiga regn kopplade till cykloner eller stormar ökar, något som idag är erkänt i hela världen. Matola, en stad i Moçambique, lider i hög grad av negativa effekter av översvämningar, främst från den år 2000. Översvämningar utgör stora utmaningar för stadsplanerare och lokalsamhällen i arbetet att främja resiliens. Den här studien undersöker dessa utmaningar. Studien fokuserar på hur utbredningen av risker för översvämning sett ut i Matola och vilka strategier, åtgärder och handlingar stadsplanerare och personer i lokalsamhällen använt för att lindra översvämningseffekter och göra anpassningar för att främja resiliens. Studien är baserad på både ett kvantitativt och kvalitativt angreppssätt, och innefattar geoprocessing med hjälp av ArcGIS för att bedöma sårbarhet och risk för översvämning i Matola år 2000, 2020 och 2040, semi-strukturerade intervjuer med stadsplanerare och personer i lokalsamhället, fokusgruppsdiskussioner med personer i lokalsamhället, samt observationer.

Resultaten visar att områdena med en låg risk för översvämning ökar i omfattning, medan områdena med en medium/hög risk minskar i omfattning från år 2000, över 2020, till 2040. Däremot sker en ökning i antalet invånare som utsätts för risk i medium/hög riskområden för medium/hög sårbarhet för översvämning med mellan 0,5-5 meters djup, beroende på den ökande, tydligt horisontella, utbredningen i landutnyttjande genom bebyggelse, i huvudsak bostäder.

Handlingar för att lindra effekterna av den stora översvämningen år 2000 fokuserade på att evakuera människor från översvämmande områden och att hjälpa dem med boende. Efter den stora översvämningen utgjordes anpassningsåtgärder av att hjälpa människor att komma tillbaka till sina hem, att flytta till nya bostäder och att bygga dräneringsdiken. Matola kommuns huvudsakliga strategi för att främja resiliens efter översvämningarna år 2000 var kapacitetsutveckling, dels genom att vidareutbilda personal, och dels genom att successivt anställa ny personal med olika kompetenser som är avgörande för planering och förvaltning av landanvändning och anpassningsåtgärder. Man arbetade också fram en ny stadsplan som tog hänsyn till faran för översvämning.

Under den stora översvämningen år 2000, var socialt kapital, karakteriserat av stark social sammanhållning och ömsesidigt förtroende bland lokalbefolkningen, en avgörande faktor för människor att komma samman för att hjälpa och rädda andra som drabbats av översvämningen. Anpassningsåtgärder i lokalsamhället efter översvämningen år 2000 var förbättringar och ombyggnation av bostäder, att höja landnivån på gårdar genom att fylla på med grus och jord, samt att många accepterade att lämna sina hem i riskområden coh flytta till de nya bostäder som byggdes av kommunen. Kommunens officiella nätverk för samarbete med lokalsamhället genom valda ledare ledde till ett fortsatt samarbete för att organisera den successiva omflyttningen av familjer till de nya bostäderna.

DEDICATION

To Jehovah God and to generations yet to be born, may they follow in these footsteps of trusting in Jesus Christ and training academically.

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Göteborg, April 2024

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LIST OF ACRONYMS AND SYMBOLS

AHPS	Advanced Hydrologic Prediction Service
ANAMM	National Association of Municipalities of Mozambique
APFM	Associated Programme on Flood Management
ARA-SUL	South Regional Water Administration
ArcGIS	Geographic Information System Mapping and Analysis Software
ArcMap	Central application used in ArcGIS, used to display and explore GIS datasets of study area, and to create and edit datasets
ASCII	Form of Raster data used in ArcMap
C40CFF	C40 Cities Finance Facility
CAPRA	World Bank LCR Probabilistic Risk Assessment Program
CENACARTA	Center for Cartography and Remote Sensing of Mozambique
CM	Council of Ministers
CMAM	Medicines and Medical Articles Center
CMAP	Chicago Metropolitan Agency for Planning
CMCM	Municipal Council of the City of Matola
CSC	Climate Service Center
DEM	Digital Elevation Model
DINAPOT	National Directorate of Spatial Planning and Ordering
DNA	National Directorate of Water
DNGRH	National Directorate of Water Resources Management
DRR	Disaster Risk Reduction
DUAT	Land Use Right Licenses
ECDC	European Centre for Disease Prevention and Control
EFAS	European Flood Awareness System
ENANPUR	National Meeting of the National Association of Postgraduate Studies and Research in Urban and Regional Planning
EU	European Union
FAO	Food and Agriculture Organization
GFDRR	Global Fund for Disaster Reduction and Recovery
GIS	Geographical Information System
GPM	Government of the Province of Maputo
GWP	Global Water Partnership
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modelling System
ICLEI	Local Governments for Sustainability
I-D-F	Intensity-Duration-Frequency

IFRC	International Federation of Red Cross
IIED	International Institute For Environment And Development
IMGW	Institute of Meteorology and Water Management
INAM	National Institute of Meteorology
INE	National Institute of Statistics
INGC	National Institute for Disaster Management
INGD	National Institute for Disaster Risk Management and Reduction
IPCC	Intergovernmental Panel on Climate Change
ISP	International Science Programme
LULC	Land Use/Land Cover
MFA	Ministry of Foreign Affairs of the Netherlands
MH	Ministry of Health
MICOA	Ministry for the Coordination of Environmental Action
MISAU	Ministry of Health
MOPHRH	Ministry of Public Works, Housing and Water Resources
NASEM	National Academies of Sciences, Engineering, and Medicine
NGOs	Non-governmental organizations
NOAA	National Oceanic and Atmospheric Administration
NZCCRI	The New Zealand Climate Change Research Institute
OCHA	Office for the Coordination of Humanitarian Affairs
OECD	Organisation for Economic Co-Operation and Development
OMS	World Health Organization
PDPMCN	Master Plan for Prevention and Mitigation of Natural Disasters
PDUT	District Land Use Plan
PEOT	Special Spatial Planning Plans
PEU	Plan of Urban Structure
PGU	General Plan of Urbanization
PNDT	National Plan for Territorial Development
PNDUH	Urban and Housing Development National Program
PP	Detail Plan
PPDT	Provincial Plans of Territorial Development
PPU	Partial Plan of Urbanization
PROL	Project for the Restructuring of Local Bodies
PSM	Procurement and Supply Management Project
SIDA	Swedish International Development Cooperation Agency
SIWI	Stockholm International Water Institute
SMS	Cell phone Text Messages
SSA	Sub-Saharan Africa
TFM	Triangular Form-based Multiple-flow
TFM-DYN	Triangular Form-based Multiple Flow Dynamic Algorithm

TV	Television
UEM	University and Eduardo Mondlane University
UFCOP	Urban Floods Community of Practice
UFRGS	Universidade Feral do Rio Grande do Sul
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Program
UNDRR	United Nations Office for Disaster Risk Reduction
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN-Habitat	United Nations Human Settlements Program
UP	Urban Planners
UPM	Pedagogical University of Maputo
USA	United States of America
USD	United States of America Dolar
USGS	United States Geological Survey
WB	World Bank
WBG	World Bank Group
WDSA	Water Distribution System Analysis Conference
WMO	World Meteorological Organization

1. INTRODUCTION

1.1. Urban floods and the challenge of building resilience

Flood occurrences are increasing globally and have been among the most frequent natural hazards with the widest geographic distribution around the world, with higher and increasing frequencies and intensities in recent decades (Ritchie & Roser, 2020; Sathler, 2014; Smith, 2013; UNDRR, 2017b, 2019a). Therefore, researchers, international and regional non-governmental organizations, as well as national and municipal governments have dedicated themselves to studying the problem of flooding. Their studies have aimed at discovering and understanding the causes, occurrence factors, and impacts of flooding, and at finding measures to help people control and live with floods and learn how to reduce their damage to society.

Climate variability, especially of rainfall, associated with the impacts of climate change is the main cause of precipitation variation, particularly in terms of positive anomalies, i.e., excessive rainfall. The increase in heavy precipitation in different parts of the world associated with changes in land cover has increased the flow of rivers, causing floods, particularly in low-lying coastal areas in the downstream portions of rivers (Fiorillo et al., 2018; Lewis et al., 2019; MFA, 2018; UNDRR, 2017a, 2019a; WMO, 2019). The location of cities in coastal areas and near the downstream portions of rivers increases flood vulnerability because it exposes the population and urban infrastructure to flood hazards and risks. The occurrence of floods in these urban areas causes great destruction of infrastructure, loss of assets, disruption of socio-economic activities, and loss of human lives (Archer et al., 2020; Houghton & Castillo-Salgado, 2017; Wagner et al., 2021). Currently, most socio-economic infrastructure, goods, and assets as well as around 55% of the world's population are concentrated in urban areas (UN-Habitat, 2023:1), a concentration expected to increase in coming decades, in turn increasing the number of people exposed to flooding (Petit-Boix et al., 2017; UFCOP, 2016).

During the period from 1950 to 2006 in Europe, floods caused casualties of nearly half of the people directly affected (UNDRR, 2016; Zhang et al., 2021), and in 2021 alone, over 500 flood casualties were reported, while thousands of people were evacuated and others displaced (ECDC, 2021:2). Human, infrastructural, and financial losses of various proportions occur in different locations across other continents due to floods almost every year (e.g., Douglas et al., 2008; Engel et al., 2017; Ficchì & Stephens, 2019; Kundzewicz et al., 2014; Little et al., 2001; Macleod et al., 2021; NOAA, 2023; OCHA, 2019; Wagner et al., 2021). Countries in Southern Africa, experienced severe floods some most highlighted in 2000, and more recently in 2018, 2019, and 2020 causing thousands of deaths and displacement (Douglas et al., 2008; Mkhandi et al., 2000; Muthoni et al., 2019; Rahut et al., 2021; ReliefWeb, 2000). Mozambique is among the Southern African territories most vulnerable to flooding, experiencing about 25 floods over the last 60 years (Christie & Hanlon, 2001; GFDRR et al., 2014; GPM, 2015; INGC, 2009;

MICOA, 2005). According to GFDRR et al. (2014), the three largest floods recorded in Mozambique occurred in the 21st century: the first in 2000 in almost all rivers, the second in central Mozambique in 2007/2008, and again in 2013. According to Christie and Hanlon (2001), the floods that occurred in 2000 were the worst in over 150 years and resulted in the deaths of about 800 people, and seriously damaged crops, livestock, housing, communication, health, education, infrastructure, and business assets. More recently in 2014/2015 and 2019/2020, there were devastating floods accompanied by strong cyclonic winds in central and northern Mozambique.

The flooding in Mozambique is caused by intense rainfall over the national territory and in neighbouring countries due to their location in the inter-tropical convergence zone. Mozambique possesses a long coastline about 2770 km along the east coast of Africa, and is located downstream of extensive river basins such as those of the Umbelúzi, Incomáti, Limpopo, Save, Buzi, Pungué, Zambeze, Licungo, and Rovuma rivers, shared with neighbouring countries, not forgetting the micro-basins of small national rivers. Furthermore, climate-change projections indicate that Mozambique is highly vulnerable to flooding, with higher expected flood risk across the country as the likelihood of direct impact from strong tropical cyclones and intense rainfall may increase over coming decades (Logchem & Queface, 2012; MFA, 2018; WMO, 2019). This reality greatly challenges Mozambican authorities to create social, economic, and land-use development plans taking account of different areas' vulnerability and exposure to flood risk. This entails integrating flood adaptation and mitigation strategies and measures in development plans to promote flood resilience, especially in urban areas with high population concentrations and many social and economic infrastructures. It also puts great pressure on the local population due to the suffering that the potential loss of property, assets, and lives that flooding can cause.

Previous studies show that, globally, the promotion of resilience to floods has been identified as an ideal path to promoting sustainable urban development and social well-being (Andreatta & Magalhães, 2011; Brown, 2016; Gupta, 2020; Smith, 2013; UNDRR, 2009, 2017a, 2019a; Wamsler & Brink, 2014), whether in terms of engineering resilience, ecological resilience, or socio-ecological resilience measures (Brown, 2016; Kelman, 2018; Vitale et al., 2020). The engineering resilience approach advocates the efficiency, consistency, and resistance of the system, emphasizing technical flood-control infrastructure and measures, such as dams, dykes, spillways, dredging, barriers, and embankments. The ecological resilience approach advocates tolerance and reorganization, emphasizing the development of satellite cities and de-urbanization by removing urban infrastructure from flood risk sites and letting areas perform their floodplain function. In turn, the socio-ecological resilience approach advocates recovery, adaptation, and change, emphasizing early-warning and emergency measures, such as disaster insurance, emergency rescue and evacuation route systems, and community facilities such as evacuation centres and temporary shelters. Other measures stressed in the socio-ecological resilience approach are the adaptation of individual houses, converting urban infrastructure to green/blue infrastructure, and promoting waterproof architecture through building regulations to adjust the built environment (Bertilsson et al., 2018; Brown, 2016; Vitale et al., 2020; Wamsler & Brink, 2014).

Promoting and increasing resilience to floods has been a challenge almost everywhere in the world. In developed countries, there is a relatively large capacity to allocate technical and financial resources to promoting and increasing resilience to urban floods. However, there have been difficulties in involving all stakeholders affected by floods (particularly urban planners and the various actors in affected communities) in participatory planning in which everyone joins in making decisions about the most appropriate strategies, measures, and actions to cope with floods (NASEM, 2019:22; Potter & Vilcan, 2020:14; Wamsler & Brink, 2014:1371). If so many challenges are encountered in promoting resilience where there are great technical and financial resources, what about the situation in developing countries where there are many restrictions in terms of technical and financial resources?

In developing countries, the difficulties of promoting and increasing resilience to urban flooding are relatively much greater than in developed countries. Urban flood alleviation strategies in many developing countries have not succeeded because of the complex alliances that exist between different actors, especially in informal settlements, which are the most affected by floods. These alliances occur between politicians, parties and their supporters, community organizations, and international NGOs, as well as between landowners, tenants, and government agencies, often around interests that are contrary to urban flood management plans. These complex alliances, whose interests are defended at all costs by those involved, have led to lack of coordination, mutual suspicion, and mistrust between those promoting change and those affected by it (Bunce et al., 2010; Douglas, 2018:270; Gupta, 2020; Nkwunonwo et al., 2016). In addition to deficiencies and difficulties in ensuring the involvement of various relevant actors and structures, especially urban planners, communities, and those interested in planning and decision-making regarding strategies, measures, and actions to cope with urban floods, there are technical difficulties and major financial limitations in promoting flood resilience (Artur & Hilhorst, 2012; Broto et al., 2015; Douglas, 2018; Gupta, 2020; Laeni et al., 2019; Nkwunonwo et al., 2016).

Previous studies reveal that in some Mozambican cities deficiency or ineffectiveness in addressing urban flood resilience actions occurs due to inefficiency and, in certain cases, lack of technical capacity (e.g., qualified technicians, computer equipment, and software) and lack of collective planning action addressing adaptation and mitigation measures involving different levels of governance and local actors (Andreatta & Magalhães, 2011; Bunce et al., 2010; ICLEI, 2017). Another factor that undermines the promotion of flood resilience in some Mozambican cities is divergent actor interests in approaching resilience actions: while urban planners take the adaptation agenda seriously, although with technical and financial limitations, the political class uses the climate change agenda for their particular interests, such as raising financial resources, while the community, faced with floods, struggles to maintain their lifestyle depending on the capacities and resources they have (Andreatta & Magalhães, 2011; Artur & Hilhorst, 2012; Broto et al., 2015; MOPHRH, 2016).

In addition to the enormous challenges of promoting resilience to urban floods, there is lack of detailed data on the occurrence of urban flood risks, such as hazard, vulnerability, and/or risk maps, especially concerning future scenarios (Hinkel et al., 2014; Muis et al., 2015), and particularly in many developing countries (CM, 2018; CMCM, 2010; Muis et al., 2015). Studies of resilience to floods indicate that the assessment of vulnerability to and risk of flooding is a fundamental activity, the results of which help in choosing strategies, measures, or actions of mitigation and/or adaptation suitable for each flood risk scenario (Ashley & Ashley, 2008; Brown, 2016; Kelman, 2018). Present and future flood vulnerability and risk assessment allows for the prediction of flood conditions as well as their impact, i.e., it describes the potential losses that the flood may inflict on people, property, and the environment (APFM, 2007; Zhang et al., 2021). Future scenarios provide both quantitative and qualitative information (e.g., about the urban areas, populations, infrastructure, and economic activities at risk) with which to assess the relative risk and particular adaptation or mitigation actions to be taken to prevent future loss and damage (Muis et al., 2015). However, the projected spatio-temporal transformations of land use generated by socio-economic development have received little attention in the flood risk projection academic community, creating a gap in research on scenarios of future flood hazard and risk in specific urban areas (e.g., Hinkel et al., 2014; Muis et al., 2015). This lack of detailed information on past flood risk, and on future scenarios in particular, undermines the choice of accurate measures to promote flood resilience in almost every part of the world, but particularly in developing countries.

1.2. Building urban flood resilience in Matola, Mozambique

In the year 2000, the Municipal Council of the City of Matola (hereafter, "Matola") suffered from one of Mozambique's most serious floods in recent decades (GFDRR et al., 2014; OMS & MH, 2008; ReliefWeb, 2000). During the 2000 floods, roads were cut and there was destruction of housing and household goods, basic infrastructure (e.g., hospitals, electrical and telephone lines, and water supply systems), various equipment, etc. (GFDRR et al., 2014; ReliefWeb, 2000). The most severely affected settlements were those located in the floodplain, the reception basins of the Matola and Infulene rivers, or in wetlands and coastal protection areas (see Figure 6.1, p. 62). While facing flood risk, Matola is also characterized by a growing urban population that increased from 424,662 inhabitants in 1997, to 671,556 inhabitants in 2007, 1,032,197 inhabitants in 2017 (INE, 1998, 2008, 2019), and 1,915,000 inhabitants in 2024 (UN World Population Prospects, 2024), increasing pressure on the access to and use of urban space. Matola is also characterized by urban growth and land use change, marked by horizontal urban spread (Araújo, 2003; UN-Habitat, 2007, 2018).

In the face of the growing threat of floods in Mozambique, the first enormous challenge in promoting resilience to floods is the lack of detailed data on the occurrence of urban flood risks, such as hazard, vulnerability, and/or risk maps of past, present, and future scenarios that could help the urban planning process to address adaptation and mitigation actions and measures to be taken to promote flood resilience. In Matola, detailed vulnerability data are scarce for assessing hazards and risks in the present and, in particular, in the future. For example, the Matola urban plan drawn up in 2010 and the Annual Contingency Plan for 2019, approved by the Mozambican government, present a map that shows areas vulnerable to flooding, but does not provide details of future flood hazard and risk scenarios throughout the

Matola area (CM, 2018:14; CMCM, 2010). Furthermore, from the year 2000 to the present, although not of the same magnitude as the 2000 floods, flooding has been frequent in Matola during the hot, rainy season (i.e., October–March), degrading social and economic infrastructures and causing loss of property and assets. These recurring floods have disrupted local socio-economic activities and growth, seriously jeopardizing urban development and degrading the quality of life of city dwellers.

Faced by the growing threat of floods and other natural hazards associated with climate change, such as cyclones and droughts, Mozambique first presented an action plan called the Vulnerability Assessment Climate Change and Adaptation Strategy in 2005, focusing on coastal protection, agriculture, and water resources. In 2008, the National Adaptation Program of Action was introduced, focusing on the three areas mentioned and adding a fourth: warning systems for cyclones, rainfall, flooding, and droughts. In 2012, Mozambique launched its National Climate Change Adaptation and Mitigation Strategy for 2013–2025, defining its mission as "to increase resilience in the communities and the national economy including the reduction of climate risks, and promote low-carbon development and the green climate economy through the integration of adaptation and mitigation in sectoral and local planning" (MICOA, 2012:14). Furthermore, these policies establish that communities affected by natural hazards and where resilience measures are to be implemented must also take part in deciding on and implementing actions together with politicians, planners, disaster risk managers, and other experts (MICOA, 2005, 2008, 2012). However, when promoting flood resilience in some Mozambican cities, the second major challenge identified by previous studies is deficiency or ineffectiveness in addressing actions for urban flood resilience (e.g., Andreatta & Magalhães, 2011; Artur & Hilhorst, 2012; Broto et al., 2015; Bunce et al., 2010; ICLEI, 2017).

In Matola, political issues, such as changes in political power and land tenure issues associated with rapid urban growth, undermine urban development targeting the promotion of flood resilience (Andreatta & Magalhães, 2011; Araújo, 2003; UN-Habitat, 2007, 2018). Since the major floods of 2000, urban planners and local communities have continued struggling to promote resilience to urban floods, although little is known about other associated challenges. Furthermore, when this study was initiated, there were no reports or studies specifically combining assessments of flood risk in the past, present, and future of Matola. In addition, for Matola there were no reports or studies specifically about what mitigation and adaptation measures and actions urban planners and the local community in Matola resorted to, and what strategic resilience approaches these measures built on, during and after the major flooding in 2000. It is in light of this lack of detailed information on past flood risk, and on future scenarios in particular, that there is a need to study flood risk assessment in the past, present, and future, and to identify the actions and strategies taken to promote and increase resilience since the floods of 2000, treating Matola in Mozambique as the case study.

1.3. Aim and Research Questions

Based on the above problem, Matola is a case study area for the wider research problem of exposure to flooding and planning to build flood resilience in a developing country's cities. The overall aim of this thesis is to investigate the challenges of promoting resilience to urban floods in Matola, Mozambique. To fulfil the aim, the following research questions were formulated:

i. How are flood hazard and risk distributed in Matola in the past, present, and future, considering the various changes in land use, population, and climate-change scenarios? How can flood-risk maps be developed given data scarcity?

ii. What flood mitigation actions were taken during the 2000 floods, and what strategies and adaptation measures were used by urban planners to promote flood resilience in Matola? How have urban planners, through urban planning, contributed to building and promoting flood resilience in Matola?

iii. What mitigation measures and actions did the communities in Matola adopt to cope with the 2000 floods? How have these communities approached adaptation measures to foster future flood resilience?

First, the study assesses the hazards and risks of flooding in Matola. The assessment is to obtain detailed data on maps of hazards and risks of flooding from the past, present, and future based on spatio-temporal projections of land use change, population growth, and climate change. The information contained in the flood hazard and risk maps constitutes an indispensable resource in the social and economic planning of the territory, particularly in urban planning, whether addressing engineering resilience, ecological resilience, or socio-ecological resilience measures. Second, the study seeks to identify the urban planners' and community members' paths in coping with floods to promote and increase resilience since 2000. It is from this perspective that this study seeks to explore how flood resilience has been addressed in developing countries context, through the case of Matola. In this study, urban planners include technicians from various specialties (e.g., architects, environmental managers, environmental engineers, surveyors, water engineers, and land-use planners) who plan and manage the ongoing use of urban land.

1.4. Rationale and relevance

Around the world, people suffer from natural hazards, whether caused by climate change or other natural phenomena. Floods are one of those phenomena that frequently occur, causing the destruction of social and economic infrastructures, means of survival, agricultural plantations, and human lives, disrupting the social and economic dynamics of families, communities, cities, and even countries. This is true in Mozambique, a developing country marked by accelerated population increase and urban growth; however, as noted in previous studies, it faces financial and technical constraints in assessing flood risk and promoting flood resilience in urban planning, and faces financial and livelihood constraints in promoting community flood resilience.

This puts great pressure on urban planning and management to meet the demand for land, considering the demographic, economic, social, and environmental issues that involve managing urban flood risks associated with the development of urban infrastructure for sustainable urban development. This challenge is severe, first, due to the lack of up-to-date and detailed information on the vulnerability and risk of flooding and, second, due to the absence of systematized information on future risks, about which there are few or no previous detailed studies, as is the case in Matola. A detailed database would help in designing realistic urban plans, conceived as instruments to guide the occupation and use of urban land integrated with measures and actions for mitigating and adapting to floods, with a view to promoting flood resilience.

This study attempts to produce detailed information on the vulnerability and risk of flooding in Matola, based on the highest magnitude and most devastating floods ever experienced, those of 2000. In addition to the 2000 scenario, there are projected scenarios for a more recent year, 2020, and a future scenario for 2040 in terms of vulnerability and risk of flooding. The results of the study could be relevant to urban planning in Matola that includes measures to promote flood resilience in the present, while also looking to the future. Furthermore, the study may contribute to and inspire the academic community addressing flood risk assessment and management, urban planners, and territorial managers in general, facilitating the development of similar flood risk and vulnerability assessment studies that look at the past, present, and future in Mozambique and elsewhere.

While studying flood risk assessment and flood resilience actions and strategies in developing countries, in the context of the technical and financial constraints and socio-political complexities facing urban planners, and of the challenges faced by members of local communities as in the case of Matola, this study aims to advance, through contextualized field studies, the academic debate on resilience from a socio-ecological viewpoint. The study explores the knowledge, experiences, and approaches that urban planners and local community members resorted to, particularly regarding the mitigation and adaptation strategies, measures, and actions used by the urban planning sector to promote city-wide flood resilience, and at the community level by the local community.

Understanding the role of urban planners and community members in the process of promoting flood resilience in the case of Matola serves as a point of reflection in the socio-ecological resilience discourse based on past experiences, showing what did and did not work, and what needs to be improved to better face future flood hazards. Such aspects from case of Matola may be relevant to addressing the promotion of flood resilience in other technically and financially constrained contexts around the world. Such insights add to the growing literature addressing how communities struggle to survive and adapt to floods and maintain or improve their lifestyles in the face of scarce resources, and how urban planners perform flood resilience actions and strategies in developing countries, under technical and financial constraints and amid socio-political complexity.

1.5. Thesis outline

This article-based thesis comprises a frame, this kappa of eight chapters, and three papers. The first chapter introduces the study, presenting the background to the studied problem and defining the case examined, aim, and research questions guiding this study. The second and third chapters are dedicated to the literature review and conceptual framework of this thesis. The second chapter is dedicated to concepts and a review of the literature on the problem of flooding. This chapter presents the concepts of danger, vulnerability, and flood risk, as well as a review of the literature on flooding in different parts of the world and on the role of flood risk assessment in urban flood risk management. The third chapter focuses on aspects of resilience. It presents the concepts of flood resilience, urban resilience, and community resilience, and reviews the literature on the paths to resilience to urban flooding and community resilience to floods. The fourth chapter consists of the theoretical framework, followed by the analytical framework of this study.

The fifth chapter contextualizes the study site in terms of its origin and development, presenting instruments that guide urban planning and the management of natural disasters, floods in particular, with a view to promoting resilience. This chapter adds insights gained from the Matola case study to illuminate the research problem, and therefore, the choice of methodological approach to be used for the study. The methodology is presented in the sixth chapter: it first presents the methodological position of the research and its design, followed by the general characteristics of the study area, the data collection and selection methods, the data analysis, ethical considerations, and the limitations of the study. This part is extremely important as it clarifies how and with what methodological procedures the study was developed and conducted. The seventh chapter presents the summaries of the three papers, followed by the conclusion of the study in chapter eight, and then the bibliography. The appendices comprise the three thesis papers and the interview guides. These three papers are as follows:

Paper I – Flood risk assessment under population growth and urban land use change in Matola, Mozambique.

Paper II – Urban planning for flood resilience: Challenges in building a resilient city under technical and financial constraints in Matola, Mozambique.

Paper III – The role of communities in building urban flood resilience in Matola, Mozambique.

Each paper has its own particular focus, and the applied methodology differs among them, but the three studies complement one another. Paper I applies a quantitative methodology in hydrological modelling, using descriptive statistics to analyse and explain the results processed using ArcGIS software regarding flood hazard (i.e., flood velocity and depth) and flood risk in Matola. Papers II and III use a qualitative methodology. Paper II analyses the actions the urban planners adopted during the major flood event, the flood adaptation and mitigation strategies for increased flood resilience they developed after that event, and the contribution of urban planning to building flood resilience under financial and technical constraints and socio-political complexities. Paper III investigates the measures, and actions the communities adopted to cope with floods during and after the major flood event in Matola, Mozambique.

2. FLOOD RISK: PROBLEMS, CONCEPTS, AND ASSESSMENTS

This literature review chapter focuses on the problems of flooding and risk and consists of three parts. First, the main problem of flooding is introduced followed by central concepts such as disaster risk reduction (DRR) and risk. The following part is dedicated to the problem of flooding, presenting what is known globally and at the regional level concerning flood occurrences as well as projections. The third part presents flood risk assessment and the different flood risk assessment models used in different regions of the world.

2.1. The problem of flooding

Floods are among the most frequent and devastating natural disasters with the widest geographical distribution in the world, causing deaths, displacement of people, destruction of social and economic infrastructure, and interruption of social and economic activities (Fiorillo et al., 2018; Sathler, 2014; UNDRR, 2017a; Zhang et al., 2021). Whether minor or major, there are different types of flooding, such as flash flooding, slow flooding, riverine flooding, urban flooding, rural flooding, coastal flooding, glacial lake eruption flooding, storm surge flooding, and infrastructure eruption flooding, resulting from various climatic and non-climatic processes (UNDRR, 2017a; Zhang et al., 2021).

Flooding usually occurs due to heavy rainfall, which can sometimes be associated with storms and tropical cyclones, overwhelming the capacity of natural waterways, drainage systems, and dams to bear the excess water flow. It can also result from other phenomena such as eruptions of glacial lakes, avalanches of large glaciers that when melting cause floods, and, particularly in coastal areas, tsunamis or excessively high tides. Dam failure or water reservoir failure triggered by technical failures or earthquakes, for instance, will flood downstream areas, even in dry weather conditions (UNDRR, 2017a).

According to Fiorillo et al. (2018:18), “increasing river discharge is recognized as being due to two main drivers: climatic variations and land cover changes. Variability in climate, and especially in rainfall, plays a significant role in discharge variation”, with an emphasis on positive anomalies, in different places on Earth. Global environmental change is potentially associated with numerous physical, environmental, and socio-economic changes that contribute to the increased frequency and/or intensity of extreme precipitation events in recent decades that have caused severe flooding in different parts of the world (Chang & Chen, 2016).

Occurrences of floods as natural disasters are increasing globally, and flood risk management to reduce their negative impacts is crucial. According to Petit-Boix et al. (2017:601), “from 1960 to 2014, flooding events accounted for 34% of the natural disasters registered worldwide (17 floods/year)”. Up to 1998, fewer than 100 floods were recorded each year, but since 1998, over 100 floods have been recorded per year (Sathler, 2014; Smith, 2013). It has been estimated that floods cause damage worth over USD 2.5 billion per year, causing about 1,200 deaths per year (Petit-Boix et al., 2017:601).

In Europe, small and large-scale floods occur almost every year. Due to climate change, which generates positive anomalies in precipitation, it is expected that in coming years, flood frequency and magnitude will increase (Koks et al., 2019). According to Santato et al. (2013:9), "for Europe as whole it is likely (66% probability) that heavy precipitation events will continue to become more frequent". Furthermore, during the European summer, the intensity of extreme downpours and the frequency of multi-day rainfall episodes are projected to increase (Santato et al., 2013). In Europe, between 1950 and 2006, floods caused many deaths and financial losses in terms of damage and associated repairs (Zhang et al., 2021). In the Mediterranean region of Europe, 812 floods killed 2,466 people in nine areas (i.e., Greece, Italy, France, Czech Republic, Israel, Turkey, Portugal, Catalonia, and the Balearic Islands) between 1980 and 2018 (Petrucci et al., 2019). On 14 and 15 July 2021, heavy rains caused disastrous floods in the Netherlands, Germany, Luxembourg, and Belgium, affecting the population and devastating infrastructure. As of 27 July 2021, 175 deaths were reported in Germany and 37 in Belgium; in addition to those 212 dead, 155 people in Germany and six in Belgium were reported still missing (ECDC, 2021:2).

Countries in the Americas also experience floods. In 2019 in the United States of America (USA), flooding inundated numerous cities and towns and millions of acres of agricultural land, causing widespread damage to houses, schools, hospitals, roads, bridges, levees, and dams, displacing thousands of people, and causing 23 deaths. The most affected areas/states were the southeast Ohio Valley, Nebraska, Iowa, Oklahoma, western Arkansas, Missouri, South Dakota, a large area between Houston and Beaumont in Texas, Minnesota, North Dakota, Wisconsin, and Michigan. These floods were triggered by severe storms with heavy rains that in some places intensified the snow melt, increasing the flooding (NOAA, 2023:9). In July 2022, eastern Kentucky and eastern Missouri were devastated by major flooding resulting from heavy rainfall from a stalled frontal system, resulting in the damage of thousands of structures, businesses, vehicles, etc., and leading to 42 deaths (NOAA, 2023:2).

Floods are the most common disaster in Latin America and the Caribbean, with 548 floods occurring from 2000 to 2019. These floods affected nearly 41 million people across Latin America and the Caribbean, and caused nearly USD 26 billion in total damage, despite relatively small numbers of deaths directly attributed to them (OCHA, 2019:16). For example, Brazil, the country most vulnerable to floods in Latin America and the Caribbean, is one of the top 15 countries in the world with the largest population exposed to the risk of riverine floods. From 2000 to 2019, Brazil was affected by around 70 flood disasters of great magnitude, affecting almost 70 million people and accompanied with deaths and the destruction of economic and social infrastructure, goods, services, and crops (OCHA, 2019).

In Asia and the Pacific, floods and storms associated with heavy rainfall are the most frequent natural disasters (UNDRR, 2016), and the Arab States region often experiences disasters from flash floods (Mouhamed et al., 2013). In Asia, floods have caused the destruction of economic and social infrastructure and agricultural crops, the displacement of people, and deaths for the last 60 years, with the Eastern, Southern, and South-east Asia regions having experienced an estimated 69,381, 127,738, and 23,930 deaths, respectively (Hamidifar & Nones, 2021). For example, between 2010 and 2016, mainland China was hit by over 10,000 flash floods that, in addition to destroying economic and social infrastructure as well as assets, caused the death of 5,496 people, representing 82% of all deaths directly related to floods during this period (Zhang et al., 2021).

Floods in Africa have also occurred frequently and have caused great damage to socio-economic assets as well as loss of life, "especially in Sub-Saharan Africa (SSA)'s cities. At the same time, the continent contains a population that is growing twice as fast [as in] other regions in the world" (Ramiaramanana & Teller, 2021:2). There is increasing exposure to floods due to increased land occupation for housing, agriculture, and livestock grazing, often in areas susceptible to flooding, and due to the growth of urban areas severely affected by floods, leading to increased risk of flooding (Tramblay et al., 2020:3). Observed climate change and extreme climatic behaviour (especially precipitation) in recent decades indicates that in Africa, prolonged heavy rainfalls may increase in frequency of occurrence and in volume, causing floods in both rural and urban areas (Ficchì & Stephens, 2019; Kundzewicz et al., 2014) and affecting many people, infrastructures, and assets (UNDRR, 2016). Furthermore, deaths due to floods have remained high since the 1950s in Africa, with figures indicating over 6,000 deaths per decade (Tramblay et al., 2020). According to Tramblay et al. (2020:3), "over the whole period 1950–2019, floods caused the deaths of 27,702 people, affecting over 82 million people, and the total costs of floods show a marked increase after the year 2000".

In the Sahel of West Africa, extreme precipitation events and consequent flooding became more frequent during the last decade of the 20th century, and projections show that they will continue to occur in coming decades (UNDRR, 2016). In the Sahel, flooding occurs particularly during the rainy season, and Mali, Niger, Burkina Faso, Senegal, and Chad are among the most affected countries. During the seasonal rains of 2020, heavy rainfall caused over 1.7 million people to be directly affected by disastrous floods, resulting in the displacement of people, loss of human lives, destruction of basic infrastructure such as houses, access roads, and property, and loss of crops, fields, and cattle (IFRC, 2021:6). In East Africa, in May 2020, areas surrounding Lake Victoria, shared by Uganda, Kenya, and Tanzania, were flooded due to rising water levels, the highest ever recorded in the lake's history, due to heavy cumulative rainfall. In Uganda, river flooding due to heavy rainfall led to the loss of basic infrastructure, crops, and livestock and to the displacement of communities living near the shore. In Western Tanzania, flooding of Lake Tanganyika affected 180 houses, some partially destroyed, that housed around 1655 people (C40CFF, 2020).

In Sub-Saharan Africa, it is currently estimated that over 71 million people live at significant risk of flooding associated with extreme poverty (IFRC, 2021). The Southern Africa region has suffered from intense cyclones associated with strong winds and heavy rains, causing flooding in rural and urban areas (Ficchì & Stephens, 2019; Mkhandi et al., 2000). This occurred in Mozambique, Malawi, and Zimbabwe in 2019 with the devastating flooding caused by tropical cyclones Idai and Kenneth, resulting in the loss of dozens of human lives, the displacement of hundreds of thousands of people, the destruction of infrastructure, thousands of hectares of crops destroyed, and livelihoods lost (IFRC, 2021:9). Another instance occurred in South Africa, where in April 2022, extreme rainfall led to floods along the east coast, causing the displacement of thousands of people, over 448 deaths, the destruction of infrastructure, and loss of crops and livelihoods. This extensive flooding was caused by extreme rainfall amounts exceeding 500 mm per day, affecting mostly the South African coastal area of KwaZulu-Natal (Mashao et al., 2023).

2.2. Central concepts of flood risk

This subsection, begin by presenting the concept of disaster risk reduction (DRR) given its relevance in understanding the interrelationship between the concepts of risk and resilience in the context of managing the risk of disasters such as floods. The central concept of risk and associated concepts within the framework of flood risk assessment – i.e., flood risk, vulnerability, hazard, and exposure – are presented.

2.2.1. Disaster risk reduction

The disaster risk reduction (DRR) concept is used in politics and academia. In politics, DRR is used in the governance agendas of international and regional organizations, as well as in countries, municipalities, and communities. In academia, DRR is the subject of research in different areas within the natural, social, and engineering sciences, to provide input for political and technical decision-making in disaster management processes from the global to individual levels (Aldunce et al., 2015; Brown, 2016; Cooke et al., 2016; UNDRR, 2009, 2019a). DRR research answers the need to respond to various natural disasters occurring in different parts of the world, to minimize or reduce their negative impacts on society. Over the last few decades, studies and reports have shown that the most frequent natural disaster globally has been flooding, followed by extreme weather (e.g., hurricanes, typhoons, cyclones, extreme temperatures, and drought), earthquakes, landslides, avalanches, wildfires, pests, and volcanic activity (Khan & Eslamian, 2022; UNDRR, 2019a).

The United Nations conceptualizes DRR as follows: “The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events” (UNDRR, 2009:4). The DRR concept points to the reduction of disaster risks as a central concern, with the primary task being risk assessment, to determine the causes of disaster risk and reduce the exposure (Cichos, 2022; UNDRR & WMO, 2012). The information resulting from risk assessment constitutes a source of guidance for preparing actions to face these disastrous events and promote sustainable development, as advocated by the Sendai

Framework[1] priorities for action[2] (UNDRR, 2019b; 2019c). Responding to or coping with disastrous events requires systematic planning in order to mitigate and adapt to existing and new disaster risks, and to increase the resilience of communities or societies, systems, and processes, in different sectors, with different territorial scopes (e.g., household, community, municipal, regional, national, and international; urban and rural), for different durations (i.e., short, medium, and long term), and involving different actors (e.g., individuals, communities, politicians, organizations, national or international NGOs, and funders) (Khan & Eslamian, 2022; Wisner et al., 2003).

Although there are specific approaches to mitigation and adaptation in relation to different disaster risks or natural hazards, in principle there should be coordination, reciprocity, and complementarity among the different actions developed, based on an overarching common plan and common objectives. This coordination and reciprocity must also occur with a view to the various existing social and governmental structures, from the national to the community, household, and individual levels. Across the world, but especially in developing countries, vulnerable people often suffer repeated, multiple, and sometimes simultaneous shocks to their families, settlements, and livelihoods, jointly reinforcing their condition of poverty and status as less privileged (Wisner et al., 2003). The availability of adequate technical, material, and financial resources is critical and fundamental; without appropriate and sufficient resources, disaster risk emergency and crisis management, as well as short-, medium-, and long-term resilience planning, are difficult to achieve (Khan & Eslamian, 2022).

2.2.2. Risk

Scientifically, the concept of risk has been extensively studied and is well known. The conception and perception of risk are relative because people (as well as communities, groups, or societies) have different knowledge and experiences of risk and choose to be concerned with some types of risks while ignoring others (Aven & Renn, 2009; Hansson, 2005; Wisner et al., 2003). However, from an objective viewpoint, a risk exists regardless of any interpretations, knowledge claims, perceptions, or subjective judgments about what constitutes the risk, what is at risk, what is the degree or magnitude of the risk, and how likely it is to occur (Aven & Renn, 2009). Risks are varied, and can be natural (i.e., natural disasters), economic, political, and social – among others. Risk is associated with uncertainty, a potential cause, and the probability of a hazardous event; it is associated with attitudes, knowledge, and experience and

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[1] The Sendai Framework focuses on the prevention and mitigation of disaster risk. It has a wide scope and applies "to the risk of small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters, caused by natural or manmade hazards as well as related environmental, technological and biological hazards and risks. It aims to guide the multi-hazard management of disaster risk in development at all levels as well as within and across all sectors. It also stresses the importance of 'multi-hazard and multisectoral, inclusive and accessible" DRR practices (UN, 2015).

[2] The Sendai Framework's four priorities for action are as follows: Priority 1 – understanding disaster risk; Priority 2 – strengthening disaster risk governance to manage disaster risk; Priority 3 – investing in disaster risk reduction for resilience; and Priority 4 – enhancing disaster preparedness for effective response and to "build back better" in recovery, rehabilitation, and reconstruction (UN, 2015).

with decision-making and action taken amid uncertainty (Hansson, 2005, 2011; Kelman, 2018; Wisner et al., 2003).

*Risk i*s the probability (or likelihood) of the occurrence of a disastrous event and includes: the possible source of the risk (e.g., riverine flooding or drought), its impact (e.g., high magnitude with high consequence, medium magnitude with medium consequence, or low magnitude with low consequence), and its frequency of occurrence (e.g., floods every rainy season) (Cutter et al., 2000:717). In the context of DRR, disaster risk is defined as "the potential disaster losses, in lives, health status, livelihoods, assets, and services, which could occur to a particular community or a society over some specified future time period" (UNDRR, 2009:4). Thus, disaster risk is a likely consequence of the combination of a potentially hazardous event and its negative impacts (e.g., losses or total/partial destruction) on lives, infrastructure, resources, and/or economic and social survival assets (Smith, 2013; Wisner et al., 2003).

Among several concepts of risk in the context of disaster risk, in this thesis *risk* is defined as the "likely consequence", that is, "the combination of the probability of a hazardous event and its negative consequences" (Smith, 2013:11). This choice is made because it presents two fundamental basic and overlapping notions in the assessment of disaster risk, the first being possible losses due to the hazardous event, and the second being the potentially unfavourable consequences of the disaster risk event. The potential of this definition in the context of risk assessment is that it makes calculations and quantitative analyses possible, along with qualitative analyses and interpretations (Kelman, 2018:286). For example, human casualties and lost homes are quantifiable, but numbers cannot express the experience of losing a family member, suffering an injury, or having to live with disabilities. Furthermore, numbers cannot express the victims' feelings concerning the future in the face of the losses suffered, and the need to redefine priorities to continue living.

Disasters are not isolated, discrete, and unique events, but rather a complex mixture of natural processes and human actions in the landscape that can result in a hazardous scenario (Wisner et al., 2003). Therefore, when managing natural disasters with a view to reducing the resulting risk, there is a need to consider human and natural factors that can trigger the event, and to consider human, material, and economic losses, including environmental degradation, as a result of the disastrous event (Khan & Eslamian, 2022; Wisner et al., 2003). Furthermore, when addressing disaster risks, it is necessary to look at the affected society's capacity to limit and reduce damage, both before and after the disastrous event. Considering the coping capacity of a society affected by a disastrous event is important because it is differentiated according to the geographic, political, and socio-economic contexts, and by the different organizational, material, and economic capacities of the social groups and individuals existing in the place, or in the affected areas (Wisner et al., 2003).

Flood risk

Flooding is the presence of water currents where a water course normally does not exist, because of heavy precipitation, dam breakage, and water overflows, or because water overwhelms the limits of the normal course of a river, lake, or sea. Simply put, floods are "the presence of water in areas that are usually dry" (Jonkman & Kelman, 2005:75). Whether it is short or long term, this presence of water negatively affects local socio-economic dynamics, degrading infrastructure and crops, injuring people, damaging goods, and interrupting traffic – among other damages. The effects are also dependent on the water depth and flow velocity, and on the local topography, type of socio-economic assets affected, and where they are located (APFM, 2007; Ashley & Ashley, 2008). For example, infrastructure in low-lying areas or floodplains may experience long-lasting floods due to the slow flow of water. However, infrastructure located in relatively high places and on slopes may experience relatively short-term flooding, but the damage can be very serious due to dragging, erosion, and the destruction of assets due to the force of the water current.

Flood risk is defined as the "probability of inundation and the associated consequences" (Sayers et al., 2013:51), and these basic components of probability and consequence can be usefully further disaggregated into their fundamental components in a flood risk analysis. First, in addition to water flow, the probability of flooding concerns the set of factors that condition exposure to flood hazard, such as rapid population growth and the occupation of flood-prone areas, land use changes and particular forms of land use and occupation, the capacity and ability of government structures to deal with flooding and land use management, and widespread poverty that reduces communities' and individuals' coping capacity. To some extent, these factors make an area vulnerable to the occurrence of floods (Chang & Chen, 2016; Fiorillo et al., 2018; Wisner et al., 2003). The consequences of the disastrous event go beyond the direct losses resulting from the direct impact, whether on humans, infrastructure, goods, or assets, also encompassing a chain of indirect negative consequences arising in the social, economic, and other spheres. These consequences are characterized, in health, by the emergence of diseases (e.g., water-borne diseases such as cholera), in education by limiting access to education due to the damage of schools, school equipment, and access routes to schools, in the local and regional economy by the loss of infrastructure and goods and by financial conditions of production that limit economic and social development. This scenario reduces the quality of life of individuals and communities, and it often takes a long time to recover through a continuous struggle (Sayers et al., 2013; UFCOP, 2016; Wisner et al., 2003).

Flood risk comprises "three crucial elements, such as the vulnerability, hazard, and exposure" (APFM, 2007:23). Several studies agree that vulnerability constitutes a key component of risk assessment and analysis. To determine vulnerability, hazard and exposure are assessed, and the results of the assessment identify the conditions that trigger the risk or the scenarios of risk (e.g., APFM, 2007; Ashley & Ashley, 2008; Kelman, 2018; Sayers, 2013; Smith, 2013).

Vulnerability is the potential for loss dictated by, first, the ability of an individual, community, society, or system to cope with hazards, recover, and maintain function, and, second, the potential exposure to a threatening hazard (Cutter et al., 2000). Thus, vulnerability is an attribute or an internal characteristic of a system, individual, or community whose structure, functioning, and layout make it susceptible to the harmful and degrading effects of external tension, stresses, or hazards (Lei et al., 2014). *Flood vulnerability* is the extent to which a system (e.g., individual, community, society, or biophysical system) is susceptible to floods due to exposure to a flood perturbation, in conjunction with its ability (or inability) to cope, recover, and maintain function – or basically adapt (Balica et al., 2013:3).

A *hazard* is a process and the occurrence of a potential threat to humans and their welfare and to the surrounding environment arising from a hazardous natural phenomenon, human activity, or substance that may cause loss of human life, injury, property and goods damage, and other individual and/or community losses or damage (Smith, 2013:11), so as to cause social and economic disruption or environmental degradation (UNDRR, 2017a). According to APFM (2007:24), a *flood hazard* is the likelihood of a flood happening in a certain place at a certain time. A flood hazard assessment aims to estimate the probability of the occurrence of this potentially disastrous flood event, and its intensity and magnitude, over periods of years to decades in order to support risk assessment and management activities (WB & CAPRA, 2016). Information about flood hazards is presented in maps and should include the boundaries of the area at risk of a "reference flood" and its intensity (APFM, 2007; WB & CAPRA, 2016). The intensity of a flood hazard refers to the combination of the horizontal flood extent of the flooded area, flood depth, flow velocity, and duration. These elements can explain the degree of impact that floods have on people, infrastructure, and property in terms of the degradation of built structures and loss of life due to the force of the water current (WB & CAPRA, 2016).

As an intrinsic part of vulnerability and hazard, *exposure* is the geospatial mapping of all existing assets in the extended flood area (WB & CAPRA, 2016:13). Exposure refers to affected parties (e.g., individuals, households, and communities), properties (e.g., economic and social, private and public infrastructure and goods of all types and uses), systems (natural or human), or other elements exposed to the hazard and subject to potential losses (Kelman, 2018:283*). Flood exposure* includes the tangible and intangible properties, goods, services, and systems possessing value of some kind, exposed to the flood hazard, or that may be subject to flooding with potential damage and losses (Beevers et al., 2016).

In analysing flood risk, the relationships or connections among risk, vulnerability, hazard, and exposure can be explained as follows: flood risk is the actual exposure of something of human value (e.g., people, infrastructure, property, goods, and the environment) to a flood hazard and is often measured as the product of the probability of losses and flood vulnerability (Smith, 2013). In fact, "the hazard potential interacts with the underlying social fabric [exposure] of the place to create the social vulnerability. The social fabric includes sociodemographic characteristics, perceptions, and experience of risks and hazards, and the overall capacity to respond to hazards" (Cutter et al., 2000:717). In addition, according to WB and CAPRA (2016:13), flood exposure information should cover at least some basic key characteristics of the population, property, infrastructure, assets, and ecosystems in question. For example, a flood risk assessment of residential properties would require exposure information on the locations of the properties, the individuals or households living in the area, the type of infrastructure, the involved assets and goods, etc. This provides data on the susceptibility of a given receptor, such as an individual (e.g., child, adult, old man, or woman), infrastructure (e.g., building, road, and bridge), and crops, to flood events (Sayers et al., 2013:51).

Specific social characteristics such as age and/or gender also affect a person's exposure to hazards and vulnerability. For example, children and the elderly are more vulnerable to flooding due to their physical limitations in being able to escape from the water stream. In many developing regions, women are also more vulnerable, as they are often the ones who stay in their homes taking care of domestic work, children, and the elderly. In flood situations, women have to save not only themselves, but also children, old people, and property, which can result in both those to be rescued and the women rescuers being dragged away by the floodwaters (Ashley & Ashley, 2008:805).

The spatial distribution of the main public services, which bring together many people, can also contribute to reducing or increasing exposure to flooding hazards. For example, many people may be exposed to the flood hazard zone if the main hospital, markets, and schools are located in areas subject to flooding, influencing the risk of harm in times of flooding. Conversely, if these services are located in safe areas, it can lessen the risks of harmful effects from flooding (Beevers et al., 2016:200). This scenario defines flood vulnerability, which embodies the flood risk. Thus, exposure is a component of hazard; in turn, exposure and hazard constitute vulnerability; the three, i.e., exposure, hazard, and vulnerability, are inherent components of risk.

2.3. The role of flood risk assessment

The heightened risk of flooding is clearly increasing globally, especially in the urban areas that bring together most of the world's population. According to Fiorillo et al. (2018:18), "the intensification of flood risk is related to a combination of factors, such as recovering discharges which raise flood probability, rapid population growth rates and widespread poverty, which reduce coping capacity and resilience", jeopardizing economic and social development. The past geographic advantage of locating cities in low coastal areas and on the banks of rivers and lakes as transport routes to facilitate trade, is now increasing vulnerability to flooding (WB, 2010).

Rapid urban growth in the context of increasing demand for urban land, and associated with limited technical and financial capacity for urban land management, especially in developing countries, leads to poorly planned and disorderly urbanization. This disorderly urban growth is making populations, urban infrastructure, assets, goods, and services increasingly vulnerable to floods (Sowmya et al., 2015:1272). Within the context of flood risk management, the legacy of past decisions (e.g., the location of existing settlements and protective measures) affects today's management choices, and the decisions made today will affect the paths taken in the future (Hart, 2011; Luu et al., 2020); the assessment of vulnerability and flood risk plays an important role in related decision-making.

According to APAFM (2007:23), "planning for the limitation of flood damage and choosing the proper methods to reduce losses incurred by flash floods requires that an evaluation of the level of the flood risk in a given area be carried out". Flood risk assessments based on future climate projections provide an important prospective view to planners (UNDRR, 2022).

Therefore, the assessment of flood risk and vulnerability and the production of flood vulnerability and risk maps are the most important, if not fundamental, strategies and tools for better flood management.

Advanced data processing techniques based on artificial intelligence, remote sensing, and geographic information systems (GIS) have been successfully employed in flood risk modelling in recent decades (Alfieri et al., 2014; Sayers et al., 2013; Zhang et al., 2021). In the late 20th and early 21st centuries, it became evident that flood disaster planning, mitigation, and recovery could be improved significantly if GIS was used to combine flood data on precipitation and water flow with demographic, social, economic, infrastructural, physical natural, and ecological information (Luu et al., 2020; Pham et al., 2022; Sayers et al., 2013; Zhang et al., 2021). Planning considering the risk of flooding and, therefore, choosing the most appropriate methods, strategies, or actions to reduce the losses caused by floods requires assessment of the risk of flooding in a given area and at a given time (APFM, 2007; Sayers et al., 2013).

Flood risk data are extremely important for urban planning, as in addition to the combination of physical, natural, infrastructural, socio-economic, and demographic characteristics of the site, they convey detailed "information on the impact of a flood of defined probability on people, the environment, and property, i.e., it describes the potential losses that the flood may cause" (APAFM, 2007:23). The flood risk information can help very structured measures to be taken, such as spatial and development planning adapted to the risk in a given region. The risk can be quantified or not, but determined probabilistically as a function of hazard, exposure, and vulnerability from expected lives lost, persons injured, property damaged, and economic activity disrupted, due to a particular hazard affecting a given area, community, society, or system during a reference period (Alfieri et al., 2014; Zhang et al., 2021).

Hydraulic modelling is central to assessing flood risk, involving the use of hydraulic models to assess and understand stream flow characteristics such as the water depth, inundation extent, and flow velocity associated with the characteristics of the land use, soil, and volume of water discharged (Echogdali et al., 2018; Ntanganedzeni & Nobert, 2020; Zhang et al., 2021). Advanced hydrological models for flood risk assessment are widely used in developed countries in pre-operational and operational flood forecasting and flood warning systems in small catchments and large basins, with short and long response times, respectively (Casagrande et al., 2017). Thus, the results of these risk assessments facilitate territorial planning and urban land-use planning, including response actions to possible future risks. Examples of such systems are the European Flood Awareness System (EFAS) used for flood warnings in Europe (Alfieri et al., 2014; Casagrande et al., 2017), the Advanced Hydrologic Prediction Service (AHPS) in the USA (Casagrande et al., 2017; Demargne et al., 2014), and other regional and national systems.

Many of these advanced hydrological flood risk assessment models are not easily accessible as they are protected by inventors and accredited users in these developed countries, whether by patents or even by complementary protection certificates, to prevent their use by third parties. In addition, these hydrological models for risk assessment require large financial investments to obtain and authorize their use, and some are very complicated to handle, requiring advanced training, and the input data required to run the models are often hard to access (Nkwunonwo et al., 2020; Nogherotto et al., 2019).

However, detailed flood risk assessment is also necessary in developing countries as the problem of flooding occurs there as well, causing damage and loss to socio-economic infrastructure, assets, and human lives, just as in developed countries. Some open-source software is available, such as the HEC-HMS software package from the USA, developed by the US Army Corps of Engineers, which has been used in hydrological modelling simulation. The HEC-HMS hydrological modelling system for flood risk assessment is based on an aggregated conceptual model, in which the physical attributes of the basin or sub-basins (e.g., the digital elevation model [DEM]), and hydrological data (e.g., precipitation data) are its two key inputs (Zhang et al., 2021). These open-access models can help in conducting flood risk assessment work, although not of the same quality as that done using the protected models mentioned above.

Therefore, researchers seek to develop models using ArcGIS that can assess vulnerability and flood risks with good quality. That is the case with the newly developed version of the triangular form-based multiple-flow (TFM) dynamic algorithm denoted the TFM-DYN model (Pilesjö & Hasan, 2014). This is an example of a model that helps in making flood risk assessments. This hydrological model simulates flow and produces estimates of water depth and velocity in an area over time using few and readily available input data on elevation, rainfall, surface roughness, and infiltration in the form of ASCII raster data processed in ArcMap version 10.5.1, which is required to run the model. This model can be used to predict the degree of flooding that a given area will incur. According to Casagrande et al. (2017:742), "early and reliable forecasting of extreme hydrological events is essential for the management of disaster risk in the cases of a flood event". These data from vulnerability and flood risk maps are fundamental for planning, adopting strategies, and developing measures and actions for flood adaptation and mitigation to promote resilience to floods, whether in urban or rural environments (Priest et al., 2016; Smith, 2013; Song et al., 2019; EU, 2018).

3. RESILIENCE: CONCEPTS AND PATHWAYS TO FLOOD RESILIENCE

This chapter reviews the literature on resilience, a central concept in this study. The first part introduces the concept of resilience and the related concepts of mitigation and adaptation. The second part presents studies of pathways to resilience to urban floods in different regions of the world, while the final part presents studies of pathways to community resilience to floods.

3.1. Resilience, mitigation, and adaptation

The concept of resilience has been widely theorized and discussed in various academic disciplines, from ecology and engineering to the social sciences. In this study, theoretical discussion of the evolution and application of the resilience concept is reserved for the theoretical framework in chapter four, while this section is dedicated to the concept of resilience in the context of disaster risk reduction (DRR) and the paths to resilience to urban flooding. In the context of DRR, resilience is defined as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (Khan & Eslamian, 2022:4; UNDRR, 2009:10). Thus, the concept of resilience presented in the context of DRR emphasizes the abilities to resist, absorb, and recover that systems, communities, and societies must exercise in the face of the disturbing and destructive effects of a hazardous and disastrous event. It also highlights that this recovery includes the possibility of preserving pre-existing functions through efficient restoration, and of possible transformations by accommodating the effects of the event (Aldunce et al., 2015; Brown, 2016; Bulti et al., 2019).

In this sense, resilience appears as a response to the risk triggered by a hazardous and disastrous event through a set of actions carried out by the community or society, or by the social system associated with the surrounding natural environment. These actions and measures in the field of risk management in the context of DRR are known as mitigation and adaptation (UN, 2023; UNDRR, 2009). In this context, mitigation is considered "the lessening or limitation of the adverse impacts of hazards and related disasters" (UNDRR, 2009:8). This means that mitigation includes all measures/actions/activities aimed at reducing harm (Cutter et al., 2000; Sathler, 2014). Therefore, the idea of mitigation is to reduce the effects of the disastrous event on systems, infrastructures, and goods, or on lives, communities, and societies (Sathler, 2014). In this concept, it is recognized that the disastrous event cannot be eliminated, but that its effects can be reduced. This means that while harm is present, the action that contributes to reducing the magnitude of harm must be taken before, for example, the flooding. For example, such actions include the use of modern flash flood forecasts, better warning and evacuation planning, and public evacuation centres (e.g., to evacuate people and goods before floods). Traditionally, the focus was on reducing the probability of flooding through extensive structural defence systems, such as barriers in flooded areas and widening river channels (Sayers et al., 2013; Singh et al., 2014).

Adaptation, in contrast, is considered to be "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (UNDRR, 2009:2). Therefore, adaptation involves adjustments to enhance the viability of social and economic activities and to reduce their vulnerability, including to current variability and extreme events as well as in the longer term (e.g., flood risks) (Singh et al., 2014). Adaptation is where the issue of accommodating the effects of the hazardous event comes in, where, if necessary, changes are made that help the affected community and society to adjust to the new socio-environmental reality resulting from the occurrence of the disaster event and its short-, medium-, and long-term effects. Considering that vulnerability, in the present case, is the extent to which a system is susceptible to floods due to exposure, adaptation actions consist of removing the exposure (e.g., resettlement in safe places), thereby reducing vulnerability (Sayers et al., 2013:4). Adaptation measures and actions rely on many non-structural options, such as actions that aim to reduce the exposure of people, the economy, and ecosystems to flooding through, for example, effective planning in flood-prone areas, prohibiting construction in hazardous areas, flood-specific building codes, and insurance arrangements (Sayers et al., 2013; Singh et al., 2014).

3.2. Pathways to urban flood resilience

Urban environments around the world are the result of interactions between a set of environmental, political, economic, social, technological, demographic, and cultural forces that operate in the construction of urban space (Pacione, 2009). Thus, urban space is the sum of these forces or overlapping layers of natural characteristics, physical geometry, and human behaviour in everyday life (Lee, 2022). Although natural elements are inevitably present, urban space is characterized by high demographic concentration, associated with the high density and concentration of typically urban service systems such as housing, transportation, education, and finance. This is marked by considerable dynamism, as urban areas are often centres of industrial, commercial, educational, cultural, and political-administrative functions (Lee, 2022; Pacione, 2009; Roy, 2016).

Urban resilience is defined as the capacity of an urban system "to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity" (Meerow et al., 2016:39). Urban flood resilience is the ability of a city to withstand flood events, absorb shocks, adjust to impacts and recover, adapt by accommodating necessary changes, and improve from the original state of the urban system in the short, medium, and long terms after the flood has receded (Xu et al., 2021).

In the context of urban flood resilience, a city should have the capacity to recover and maintain the socio-economic dynamics that existed before the shock. Thus, the city should keep possible future flood risks at tolerable levels through both mitigation and adaptation actions and measures that incorporate innovations to avoid loss of life and injuries. This includes preventing and minimizing damage to infrastructure and assets, and interruptions of activities during future floods by installing rapid recovery capacity. In addition, in the context of urban flood resilience, there should be sufficient installed capacity to manage the quality of water for consumption, considering drainage and sewage systems and other infrastructure, and guaranteeing welfare, social and economic equity, and environmental quality (O'Donnell et al., 2019). Therefore, in defining resilience to floods, the concept explores the development of flood resilience measures that combine best approaches to promoting resilience. This includes urban mitigation and adaptation measures, which are considered essential steps to reduce flood risk and better prepare for future hazards.

In flood risk management in the context of urban planning, there are different approaches based on three discourses of urban flood resilience found in the literature: engineering, ecological, and socio-ecological resilience (Liao, 2012; Norizan et al., 2021; Vitale et al., 2020; Wamsler & Brink, 2014). According to Vitale et al. (2020:2), "the discourses of engineering, ecological, and socio-ecological resilience provide distinctive approaches and prescribe different roles for spatial planners".

The engineering approach to urban flood resilience aims to keep floods away from urban areas (Liao, 2012) or to reduce or avoid flood hazard (Wamsler & Brink, 2014) through structural technical measures, such as dams, dykes, spillways, dredging, barriers, embankments, and storm surge barriers. The engineering resilience approach also fits with the use of spatial measures such as river widening, river basin retention, infiltration areas, water storage, polders, and wetlands, oriented to flood probability reduction (Norizan et al., 2021; Vitale et al., 2020).

The ecologically oriented approach to urban flood resilience aims to preserve existing natural areas and protect biodiversity by limiting urban settlement to safer areas and impeding urban expansion into floodplains (Vitale et al., 2020; Wamsler & Brink, 2014). The goals of this approach can also be attained by removing urban infrastructure from flood risk locations and allowing floodplain areas to perform their natural function, or by increasing the percentage of floodable area and decreasing dependence on flood control to reduce the flood exposure of people, infrastructure, assets, and goods (Liao, 2012; Vitale et al., 2020).

The socio-ecological approach to urban flood resilience emphasizes the role of citizens, local communities, urban planners, managers, and policymakers in enhancing flood resilience by redefining land-use and building regulations and by making socio-economic adaptability more flexible. Urban planners, managers, and policymakers, by involving local communities, can organize themselves, plan the measures to be taken, and decide to protect themselves along with their urban infrastructure, assets, and goods through green infrastructure, waterproof architecture, drainage system improvement, and disaster insurance (Norizan et al., 2021; Vitale et al., 2020), or by no longer developing urban areas in flood-prone areas (Liao, 2012; Norizan et al., 2021). Urban planners, managers, and policymakers, together with local communities, may also decide to prepare for evacuation to public spaces in emergencies, to facilities such as evacuation centres and temporary shelters whenever flooding occurs (Bertilsson et al., 2018; Vitale et al., 2020). The socio-ecological resilience approach mainly adopts combined technical, structural, and non-structural spatial measures such that "warning systems, adjustments to the built environment, and flood-oriented land use dispositions may all enhance urban flood resilience" (Vitale et al., 2020:4).

Note that the measures and actions to promote and build resilience to urban floods described in the three resilience discourses above have been developed within urban planning. They involve dealing with infrastructural, economic, social, and environmental elements essential to urban development. However, the promotion and building of resilience to urban floods depends on geographical contexts, which are generally differentiated, whether from the perspective of the natural or constructed environment and its physical characteristics, or in terms of their political, economic, and social characteristics. Furthermore, the approach to resilience to urban floods depends on the existing structures and organizational capacity as well as on the material and economic conditions of the government and of the social groups and individuals existing in the affected location or urban spaces. This means that urban planning is fundamental to promoting urban flood resilience (Vitale et al., 2020; Wisner et al., 2003).

Urban planning is a professional practice of deciding how to achieve a set of objectives based on a set of policies, on socio-economic, physical, and natural data on a territory, and on practical actions, technically constituted and executed to create or enhance the urban fabric (Pollalis & Macris, 2008). Urban planning is part of a certain regulatory situation in public administration, based on networked governance and agency that involves different actors and structures in planning and managing the city. Therefore, urban planners and managers cooperate with other types of professionals with the aim of achieving the desired goals (Sehested, 2009). Urban planning has been developed mainly by public administration and in response to the need to reform the use of urban land and the types and characteristics of infrastructure for services such as housing, transport, commerce, industry, recreation and leisure, green areas, urban sanitation, public health, and education that constitute the urban fabric. The goal is to improve the urban environment and development from the social and environmental well-being perspective, and in terms of the efficiency of distributing services and of the urban economy (Pollalis & Macris, 2008; Sehested, 2009).

Within urban flood resilience, the political and governmental context of urban planning expresses the political will to design strategic policies and urban plans that integrate measures or actions aimed at promoting or increasing resilience. This favours the creation of economic and technical conditions through mobilizing financial and technical resources to finance and support the actions to be carried out to promote resilience to urban floods. The existing capacity of social structures and groups to deal with urban flooding in communities and society is critical in promoting resilience to urban flooding. This is expressed by financial capacity, well-being or poverty levels, and the ability to self-organize and respond to local problems individually and collectively (Bulti et al., 2019; Vitale et al., 2020; Xu et al., 2020).

Several cities worldwide that regularly suffer from floods have developed measures and actions to promote and increase urban resilience to floods. Below, six examples of the promotion of resilience to urban floods are presented. The studied cities were selected taking into account several basic criteria: first, these are large urban centres affected by flooding; second, three of these cities are located in developed countries, and the other three are located in developing countries. This choice aims to visualize which resilience measures have been applied and under what conditions.

The first example is Milan in Lombardia, Italy, which is one of the most economically developed and densely populated areas in Europe. Since the 1950s, increasing urbanization of the Lombardia region, with an emphasis on Metropolitan Milan, has crossed the River Lambro and its tributaries, reducing the water storage capacity of the river. This urbanization has consequently increased the risk of flooding, due to the potential infrastructural, economic, and human damage that flooding events may cause in the region (Raimondi et al., 2020; Vitale et al., 2020). Although it involved different sectors of society, and actors such as political actors, urban planners, and local communities, urban planning played a major role in integrating actions aimed at promoting resilience to urban floods in Metropolitan Milan (Vitale et al., 2020). These measures and actions entailed reviewing policies and urban plans and identifying specific areas and actions to be developed. According to Vitale et al. (2020:5), "to mention a few of them, in 2014, the Lombardia region prescribed no urbanization on virgin soil and, in 2017, launched the principle of hydraulic and hydrological invariance". The purpose of these measures was to preserve existing natural areas, which also serve as infiltration areas and protect the remaining biodiversity (Raimondi et al., 2020; Vitale et al., 2020). Based on the principle of hydraulic and hydrological invariance launched in 2017, "for any new land use transformation compensations are required in terms of water lamination (temporary overflow), infiltration, and interception" (Vitale et al., 2020:5).

In terms of structural interventions, Metropolitan Milan invested in engineering measures and built flood control infrastructure, such as dams and dikes, spillways, dredged channels, embankments, and barriers. Dikes and dams were intended for water storage and to keep certain portions of land dry by damming running water, especially in times of flooding. Dredging consisted of cleaning, desilting, widening, clearing, removing, and excavating material from the bottoms of rivers and channels to keep the water in the channels and facilitate its flow. The spillways discharge all the unused water to allow for the disposal of flood waters. Other measures applied were embankments to raise the ground level and barriers to prevent the invasion of flood waters. These engineering measures were seen as the most effective ways of addressing the flood risk problem in Milan's greater metropolitan region. "Non-structural measures, such as early warning systems and emergency measures, were also implemented to reduce flood vulnerability" (Vitale et al., 2020:8). In addition to promoting the education of local communities about the risk of flooding, flood insurance was introduced to guarantee payment for material damage of sudden, unforeseen, and accidental origin caused by floods (Vitale et al., 2020).

Another example of resilience pathways is found in Kingston upon Hull, the UK, a densely populated region located at the confluence of the River Hull and the Humber Estuary, an area on the East coast of Northern England naturally vulnerable to pluvial, fluvial, and tidal flooding. According to Dieperink et al. (2018:5), "this case study is indicative of the situation in England, where all FRMSs [i.e., flood risk management systems] have been present for many years and in which overarching policy is often established at the national level but delivered at the local level". In addition, the flood risk management actions are closely linked with European policies and plans, and were implemented with the participation of local communities down to the individual level, with private sector recognition and support (Dieperink et al., 2018; Fletcher et al., 2019).

This region has suffered cyclical floods of small magnitudes, but those of 2007 were among the most devastating, prompting great planning, financial, and technical efforts to promote action and increase resilience to floods. The development of flood resilience measures was based on a joint strategy between nearby towns, including the upstream East Riding of Yorkshire Council and Hull City Council itself (Dieperink et al., 2018). An upstream flood storage structure to reduce downstream flood risk constitutes the most advanced strategy. However, drainage and land defences constitute the dominant flood risk management system, including the maintenance and strengthening of the river and coastal defences within the city. Small-scale floodwater storage facilities at recreational sites, green areas, and other multipurpose areas, such as football fields and parks, have also been constructed (Dieperink et al., 2018; Fletcher et al., 2019).

An early warning system was also implemented, consisting of hydrological modelling based on updated data for accurately forecasting floods. Warnings are issued, not only through communication and information channels such as TV and radio, but also by email, fax, telephone, and SMS text messages. The development of these diverse mitigation and adaptation measures to increase and promote flood resilience has been funded by national flood management funds, funds from locally generated taxes, European funds, and other regional fundraising schemes such as the Humber Local Enterprise Partnership (Dieperink et al., 2018:6). Flood management in this region has relied on diversified measures, with great technical and financial support, enabling success in the actions developed to increase and promote resilience to urban floods (Dieperink et al., 2018; Fletcher et al., 2019).

Another interesting example of urban flood resilience is the case of the Chicago region in the USA, where actions taken to increase and promote resilience to urban floods reflect the determination of government officials and politicians, congressmen, and the local senate. At the level of the Chicago metropolitan area, a regional plan was developed addressing macro-flooding resilience actions with the Chicago Metropolitan Agency for Planning. One measure comprised major engineering works that have been designed and completed, including a network of stormwater reservoirs, "including the Thornton Quarry Reservoir, which has the capacity to store 7.9 billion gallons of stormwater", and a network of around 160 km of tunnels for collecting and channelling floodwaters (NASEM, 2019:22).

In the city, several actions to promote urban resilience were planned and have been carried out, such as the construction and rehabilitation of drainage systems and the reconstruction of sewer systems, carried out jointly by Chicago's Water Management Department and the Chicago

Metropolitan Agency for Planning (CMAP, 2017; NASEM, 2019). In addition, 85 local projects funded by the Cook County Metropolitan Water Reclamation District to control and channel stormwater have been developed at various locations throughout the city (NASEM, 2019:22). Other actions carried out within the framework of promoting resilience to floods are the construction of rainwater irrigation systems in gardens, urban parks, schools, and elsewhere in the city. One local initiative supported by the local government was the creation of resident neighbourhood flood groups, namely, Floodlothian Midlothian, Stop Elmhurst Flooding Now, RainReady Chatham, and Ixchel. These groups advocate for assistance from the local government and planning sector, and share information and updates on any activities, events, or situations concerning flooding or actions taken to promote flood resilience (CMAP, 2017; NASEM, 2019). All actions to increase and promote resilience to urban flooding in the Chicago Metropolitan area, including at the regional, city, and county levels, which support neighbourhood activities, are based on coordinated actions between various public and private actors, including the US Armed Forces, with urban planners and managers playing a central role. Urban planners had a great role in reconciling the different viewpoints and interests of different groups in action plans and in managing and monitoring the implementation of measures and actions to promote flood resilience These actions consist of up-to-date advanced flood risk assessment studies, consultations, sectoral planning, early warnings to citizens at all levels, and channelling sufficient funds into short-, medium-, and long-term actions, significantly minimizing the negative impacts of floods (Casagrande et al., 2017; CMAP, 2017; Demargne et al., 2014; NASEM, 2019).

In turn, in developing countries, such as Thailand, a country that suffers from cyclical floods, particularly in the capital Bangkok, measures to increase and promote resilience face hindrances, often due to technical and financial limitations. The existing system of flood risk management integrated into urban planning, to increase and promote resilience in the city of Bangkok, focuses on structural measures. These measures are intended to protect infrastructure and focus on expanding, building, and maintaining drainage infrastructure, primarily to protect and maintain the growth of economic activity in the real estate development and tourism industries without any serious interruption due to floods (Laeni et al., 2019). Bangkok's practical measures integrated into the flood resilience strategy consist of "the heightening of dikes along the Chao Phraya River, the construction of more large drainage tunnels, and increasing the drainage capacity of canals" (Laeni et al., 2019:161). Furthermore, there have been difficulties conducting up-to-date and detailed flood risk assessment studies due to the lack of instruments for flood assessment. Such assessment results would provide detailed information on which urban areas are particularly vulnerable to flooding, in order to develop new detailed land-use plans based on flood risk (OECD, 2018).

According to Laeni et al. (2019:163), "an economic growth frame is dominant in the development of the Bangkok Resilience Strategy. In practice, structural flood protection and drainage infrastructure remain the dominant strategy to protect the city and safeguard economic development". Although Bangkok's flood resilience strategy theoretically attempts to integrate broader socio-economic benefits for the entire urban population, concrete measures and actions to achieve this objective seem to be lacking. Furthermore, community involvement in the planning process is limited, obviously hindering actions to effectively meet citizens' aspirations for flood mitigation and adaptation measures that address their interests (Laeni et al., 2019). Despite the large investment in structural measures, other social aspects inherent in resilience to urban floods, such as local community involvement, have been ignored. This is not an ideal path to resilience, since communities are part of the urban system and have knowledge and experience of floods that can be valuable in planning and for strategic actions to manage urban floods.

In the densely populated greater metropolitan region of Lagos in south-western Nigeria, practices promoting resilience to urban flooding, integrated into Lagos' urban planning strategies, first, consist of structural measures along the existing river and channels. Actions such as expanding and maintaining drainage infrastructure, annually removing debris from or dredging drainage channels in the heart of the city, and demolishing houses in areas subject to flooding are carried out. Second, in cooperation with the urban planning sector, non-structural measures are carried out, such as raising residents' awareness in areas at risk of flooding, such as floodplains and wetlands, so they will move to other relatively safe areas or to accept resettlement, as in the Ogun River case (FSDAfrica, 2021; Nkwunonwo et al., 2016). However, in the chosen strategies, technical and financial constraints also exert an influence, somewhat limiting the effective and efficient execution of these measures. One of these difficulties concerns managing urban land, in which the responsible entities claim that there is limited non-flooding land in which to resettle needy families, given the vast areas prone to flooding in the region. Financial resources, in turn, limit the resettlement process, with families waiting a long time to receive plots of land and receiving appropriate compensation for demolition losses incrementally over a long period. Worse still, there are situations in which families are not even allocated plots or compensation for demolition losses, as in the cases of the August 2011 demolitions in Agege and Ijeshatedo, and of the 2010, 2012, and 2013 demolitions in Ijora-Badia (Nkwunonwo et al., 2016). That is why, regarding managing the needs of residents regarding measures to promote resilience and sustainability, Nkwunonwo et al. (2016:358) noted that "the achievement of government's urban sustainability goals (which include general flood management measures) in Lagos are often without regard to the needs of the poor residents of the area".

Another African urban area that frequently suffers from urban flooding is Greater Accra in Ghana. The measures integrated into urban planning by the Metropolitan Assembly of Greater Accra with a view to promoting resilience to floods basically consist of structural measures, highlighting the construction and maintenance of drainage systems and the dredging of rivers to unblock major waterways before the rainy season. Associated with these measures, unauthorized buildings near water courses were demolished to allow the free flow of water. These demolitions have offered a short-term solution because the demolished structures are rebuilt by the population soon after the demolition (Owusu & Obour, 2021).

According to Douglas (2018:267), the "wide gulf in living standards; the differences in the social goals of the wealthy elite and the poor; and the repeated failure of public participation and consultation" all complicate the situation. The Accra scenario reveals a lack of collaboration in efforts to promote resilience to urban floods between city management authorities and local communities. Moreover, this reflects a failure of public participation and consultation within the scope of actions to promote resilience to urban floods. This also reveals weaknesses in urban land management, and in the technical approach to urban flooding in Accra, which normally should be inclusive, as it is a problem for all city dwellers. In addition to financial difficulties, to some extent, it reflects weaknesses in the development of detailed and accurate studies not only of the environmental and infrastructure impacts resulting from flooding but also of the socio-economic impacts, taking careful account of the neediest (Douglas, 2018; Owusu & Obour, 2021).

3.3. Pathways to community flood resilience

The concept of community is complex, carrying with it different interpretations due to different uses in research. In this study, by a community we are referring to a group of people who have certain common characteristics (Bulti et al., 2019; Twigg, 2009). According to Twigg (2009:9), "in conventional emergency management, communities are viewed in spatial terms: groups of people living in the same area or close to the same risks". However, a community must be seen, beyond the spatial aspect, also in terms of fundamental community dimensions such as common interests, values, norms, and social structures socially constructed and established over time that characterize and identify groups of people. These elements are the ones that truly express and explain how communities are socially constructed and the paths they choose to address common challenges (Archer et al., 2020; Bulti et al., 2019; Xu et al., 2020; Twigg, 2009). Furthermore, when studying a community, in addition to looking at social and administrative services, and public and private infrastructures, it is important also to consider its relationships with external forces and its networks of socio-economic and political connections that influence these relationships (Archer et al., 2020; Twigg, 2009).

The conceptual development of community resilience is relatively new, being among the socio-ecological resilience approaches and being strongly linked to the sustainability of social systems, where communities play a key role in building and promoting resilience (Berkes & Ross, 2013; Bulti et al., 2019). Community resilience is oriented to the study of how communities promote and increase resilience to various social and natural phenomena that impact the lives of communities, from a cultural, health, professional, financial, including environmental perspective (Archer et al., 2020; Brown, 2016; Bulti et al., 2019; Twigg, 2009).

Community resilience is defined as the ability of a community to prepare for potential hazards, withstand the devastating effects of the event, adapt by making necessary changes, recover quickly from disruptions, innovate, and improve common well-being (Xu et al., 2020). This means that in community resilience, community members are the primary active agents in shaping their well-being and capacity to mitigate risks and adapt to change; in this, they intentionally develop their individual and collective capacities, and come together to respond and influence actions and measures taken to mitigate and adapt to hazards, and to sustain and develop the community to meet future events (Berkes & Ross, 2013; Magis, 2010). Community flood resilience is the ability of a community across its social, spatial, and temporal scales to resist and maintain desired functions in the face of flooding, and to quickly return to the desired dynamics after the flood event and adjust and change accordingly, through transforming, innovating, and strengthening the current and future adaptive capacity (Bulti et al., 2019).

The extent to which a community can demonstrate resilience following a disaster largely depends on the local context, i.e., the properties, attributes, or characteristics of the community in which the disaster occurs, which can be expressed in different dimensions. The dimensions of community resilience are the properties or characteristics of communities needed in order to develop actions, measures, and strategies to build or improve flood resilience (Bulti et al., 2019; Wickes et al., 2015). The dimensions of community resilience systematize a set of characteristics of individual and collective livelihood resources, such as economic, natural, social, cultural, local/traditional knowledge, and political resources, that help in analysing how communities build or promote resilience to flooding (Archer et al., 2020; Berkes & Ross, 2013; Bulti et al., 2019; Wickes et al., 2015). Therefore, the dimensions, attributes, or properties of community resilience can comprise: financial or economic; physical/material; environmental; social/cultural capital; community information competence and communication; and institutional and organizational dimensions (Archer et al., 2020; Bulti et al., 2019). Furthermore, when approaching community resilience, it is essential to consider the different aspects of the local context, such as the sometimes conflicting subgroups and multiple interests within the community that characterize and enhance it, but may undermine the building or promotion of flood resilience (Arnall, 2015; Bulti et al., 2019; Wickes et al., 2015).

Below, these community resilience dimensions are explained, and six examples of the promotion of community flood resilience are presented. The examples were selected, considering each dimension, to demonstrate how each dimension of resilience can enhance resilience to floods based on practical examples.

The *financial dimension* refers to the current economic situation and the capacity to sustain and stimulate economic growth, influencing the community’s ability or capacity to prepare in advance to face possible disasters and recover from a flood. It includes the diverse income sources of individual community members and access to financial resources for investments or to meet needs. The existence and improvement of financial capital can facilitate and improve individuals’ capacities to face disasters and accelerate the recovery process (Bulti et al., 2019). Indeed, economic security and stability at the local community level play an important role in building and increasing resilience to floods. The existence of mechanisms giving low-income households access to financing will allow them to obtain essential goods for subsistence, but will also permit investments that create financial security, contributing to the accumulation of assets to reduce urban poverty and enable more effective and inclusive transformative adaptation through short-, medium-, and long-term planning (Archer et al., 2020:172). For example, the creation of residential neighbourhood flood groups, such as Floodlothian Midlothian and RainReady Chatham, supported financially by the Chicago government, was a measure or mechanism to give access to financing needed due to flood impacts. Among the many activities of these groups, such as sharing information and updates on activities and promoting resilience, they give the local government information on families or local community members who would need financial assistance if their properties and assets were destroyed by floods (CMAP, 2017; NASEM, 2019). Individual and collective assets such as savings, properties, and physical goods, in addition to being survival resources that help improve the financial and social conditions of families and the community, can support flood mitigation and adaptation, as they can also facilitate access to financial resources such as credit that can improve financial conditions in times of crisis to promote social and economic recovery (Bulti et al., 2019). Legal access to land plays an important role in the economic strengthening of communities. In addition to being used for agriculture, livestock, and other land-based activities, land can be leased and generate useful economic benefits advancing collective or individual action to promote resilience (Archer et al., 2020).

The *physical dimension* indicates the ability of the physical component, including the built environment and existing infrastructure, to function at acceptable and sustainable levels during and after a flood. For a resilient community, existing infrastructure and facilities must be effective, performing their role in controlling water to minimize damage, and they must also be robust and function well during and after floods. Furthermore, for effective flood emergency management, emergency shelters, survival equipment, and basic assets such as food kits and healthcare must be part of the infrastructure, facilities, and community services available and accessible in a resilient community (Bulti et al., 2019). For example, in the Vietnamese Mekong Delta, since the floods of 2000, durable houses with granite and concrete walls and sheet metal roofs have become more common. The houses and other local infrastructure were raised, creating gaps between the floor panels and the ground to reduce the force of waves against these structures during storm floods. The height of the house above ground depends on experience, i.e., the highest flood peak in the past, and over two metres above the ground is the height that most families have managed to raise their houses (Liao et al., 2016). In fact, this ecological practice of flood resilience in the Mekong Delta communities, of living with floods based on the perception that floods are part of their lives, is a great example of the physical dimension of resilience in the community. With these measures, the paths and roads in Mekong Delta communities continue to be used in the rainy season but, depending on the degree of flooding, with small boats. The social and economic dynamics of urban communities continue and coexist both with and without flooding, and this shows that learning from disasters is an essential element of resilience (Liao et al., 2016).

The *environmental dimension* refers to the “availability, accessibility, and management of natural resources such as water and land that provide space to live and work” (Bulti et al., 2019:5). Effective management of available and accessible natural resources plays a significant role in increasing and promoting community resilience to flooding. For example, the correct allocation of land for housing infrastructure, for commercial and industrial infrastructure, and for agriculture, green areas, and wetlands for storing flood waters can certainly absorb the impacts of floods and facilitate the recovery process (Bulti et al., 2019). Policies that influence access to assets, such as legal access to land, play an important role in promoting community resilience to flooding. With security of land tenure, communities can use their land for various purposes, such as agriculture and livestock farming, improve their housing, businesses, and infrastructure, and increase and strengthen the security and value of physical and socio-economic assets and the land itself, thus strengthening resilience (Archer et al., 2020). A study of community flood resilience in rural Malawi found that participants from the uplands owned proportionally more land in both the uplands and lowlands for livelihood activities. Participants from the lowlands did not own land in the uplands, but they had an alternative place (in the uplands) to flee to during floods. This finding reveals two communities that have learnt to interact with their socio-ecological environment to sustain their livelihoods and therefore can risk living in harm's way (Dewa et al., 2022).

The *social/cultural capital dimension* refers to the available social resources that a community resorts to or can use to promote or increase resilience, maintaining their means of subsistence during and after a flood event (Bulti et al., 2019). The existence of structured, effective, and sufficient social capital can improve and support collective solutions for the challenges and difficulties that arise due to floods, protecting and restoring the conditions for community subsistence and improving cooperation and trust between community members (Bulti et al., 2019; Ntontis et al., 2019; Xu et al., 2020). Its main features are strong social networks, supported by a well-established foundation of trust and participatory and inclusive processes, within the community and between the community and other interested or relevant bodies in the territory. The existing social networks indicate the level of cohesion and community bonds that facilitate communication, organization, (re)organization ability, collective activity coordination, and social cooperation, all for mutual benefit (Bulti et al., 2019; Wickes et al., 2015), and play a critical role in community flood hazard response, coping, and recovery (Xu et al., 2020:2). A study of the physical and social determinants of mortality due to a tsunami in the Tohoku region of north-eastern Japan found compelling evidence that social capital, i.e., community social ties within and beyond communities, influenced the survival of the affected community. Deeper trust and more social cohesion made collective evacuation behaviour more likely across the Tohoku area and reduced mortality in the flood disaster caused by the tsunami on 11 March 2011 (Aldrich & Sawada, 2015:72–73).

Linked to the social/cultural capital dimension is *community competence*. The *community competence dimension* indicates "the reality that community resilience is both 'bouncing back' and 'bounce forward' through a rigorous and energetic effort which depends on the capability of a community to creatively envision a new future" (Bulti et al., 2019:6). It essentially captures the diverse capabilities of a community, such as the ability to develop solutions to complex problems and to participate in significant political and cooperation networks. It also captures the community's perceptions about bringing about positive changes, making decisions, and collectively believing that it is capable of rebuilding, restructuring, and generating an ongoing or new local socio-economic dynamic in the face of adversities caused by natural disasters, such as floods. As shown in the case of the Vietnamese Mekong Delta, after the floods of 2000, communities collectively believed in themselves and collectively changed the type of housing construction, raising the floors of houses, adapting to flood risk levels, and collectively learning to live with floods (Liao et al., 2016). The local authorities adopted this housing form as a construction standard in those areas at risk of flooding in the region (Archer et al., 2020).

The *institutional and organizational dimension* refers to institutions and services responsible for managing disasters caused by floods in order to promote and build resilience. This dimension specifically indicates “the effectiveness of relationships among and within community organizations and entities” (Bulti et al., 2019:7). The level of a community’s resilience is also influenced by the capacities outside it, in particular, by disaster management services and other administrative and social services, public services and infrastructure, and a web of socio-economic and political cooperation linkages with the wider world (Twigg, 2009). In Bangkok, for example, district offices and municipalities also have the scope to integrate community visions, schemes, and local knowledge into city-level plans, to reduce the disconnect between official approaches and community and individual approaches to dealing with crises in the future. Therefore, policies that influence access to assets are very important, as they ensure that flood-proof designs are integrated as the norm in all infrastructure projects, such as housing, in flood-prone neighbourhoods (Archer et al., 2020). Another example was mentioned above, in which local authorities in the Vietnamese Mekong Delta, after the floods of 2000, adopted as a standard construction strategy in areas at risk of flooding in the region, that floors of structures should be raised above the highest level of the most devastating floods in the past (Liao et al., 2016). This required effective and committed participatory planning and implementation with accountable and effective community, district, and municipal leadership, characterized by inclusive governance involving government, business, the community, and civil society, and applying evidence-based decision-making committed to promoting and increasing community resilience to flooding (Bulti et al., 2019).

4. THEORETICAL FRAMEWORK

This chapter presents the theoretical framework and concepts used to create the analytical lens used in this thesis. The chapter is divided into three parts. The first part explores the application and evolution of the concept of resilience, specifically resilience in relation to natural disaster risk management. The second part deals with the social actor/structure theoretical approach, and the third presents the analytical framework, which brings together the theoretical perspectives and explains how these are applied in this study.

4.1. Resilience Theory

4.1.1. From ecological resilience to socio-ecological resilience

Some authors suggest that the concept of resilience arose in ancient mathematical thinking (Mackinnon & Derickson, 2012) and in physics (Aldunce et al., 2015). In these fields, resilience is described as "the ability of a material or system to resist without breaking and the speed with which it returns to equilibrium after displacement" (Aldunce et al., 2015:2). Others point out that the concept was used in research by Garmezy, Werner, and Smith in the fields of psychology and psychiatry in the 1940s. Psychology sought to study, understand, prevent, and treat mental health problems such as schizophrenia and autism resulting from natural stressors, such as prenatal risk in the family, death, poverty, and trauma (Aldunce et al., 2015; Brown, 2016; Mackinnon & Derickson, 2012). In this field, resilience is defined as "the ability of individuals and communities to resist and return to baseline functioning after a stress, disaster or external shock" (Aldunce et al., 2015:2).

However, when analysing the history of applying the concept of resilience, researchers clearly agree that it was in ecology that the concept became established in the 1970s (Aldunce et al., 2015; Brown, 2016; Mackinnon & Derickson, 2012). According to Brown (2016:72), the "resilience ideas in ecology emerged from studies of interacting populations of predators and prey and their functional responses in relation to ecological stability theory". In ecology, the resilience concept was scientifically deepened by Holling's studies, the main one being "Resilience and Stability of Ecological Systems", published in 1973 (Aldunce et al., 2015; Brown, 2016; Cutter et al., 2008; Mackinnon & Derickson, 2012; Olsson et al., 2015; Turner, 2014). Holling's seminal paper "explored the existence of 'multiple stability domains' or 'multiple basins of attractions' in natural systems and how they relate to ecological processes, random events such as disturbance, and different temporal and spatial scales" (Brown, 2016:72).

The applications have since then extended beyond ecology, and resilience is now a multifaceted concept adapted to different uses and contexts (Alexander, 2013; Brown, 2016). As mentioned in section 3.2, there are currently three main discourses of resilience: ecological, engineering, and socio-ecological resilience (Brown, 2016; George, 2019; Vitale et al., 2020). According to Holling (1973), ecological resilience "determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist" (Olsson et al., 2015:1). Therefore, the need to absorb or incorporate the changes resulting from a disturbance presupposes the transformability of the functioning of the variables necessary for the system to persist. Thus, based on the assumption of ecological resilience, which includes the ability of the system to "absorb changes of state variables", the resilience of the system can also mean its transformation through the emergence of new structures and behaviours of the variables absorbed by the system (Mackinnon & Derickson, 2012:256).

Unlike ecological resilience, which focuses on natural ecosystems, engineering systems are products of intentional human inventions. The engineering resilience discourse focuses on ensuring the continuity and efficiency of the system's functioning during and after failure (Mugume et al., 2015; Vitale et al., 2020). Engineering resilience is "concerned with the stability of a system near to an equilibrium or steady state, where resilience is defined in terms of elasticity which emphasizes resistance to disruption and speed of return to the pre-existing equilibrium" (Mackinnon & Derickson, 2012:256). It is called engineering resilience because, in the case of urban flooding, for example, the engineering systems, such as drainage channels, bridges, water reservoirs, and other infrastructure, are designed to deal with the great shocks and stresses caused by flooding, and quickly return to normal when the disturbance and stresses are removed (Brown, 2016). Engineering resilience focuses on stability, the time to return to the pre-existing equilibrium, the "single equilibrium" or "steady state"; however, these are properties that critics of engineering resilience point out as a limitation or weakness of this resilience approach, since "new systems may be created in response to disturbance; in other words … they might self-organise and show adaptive capacity" (Brown, 2016:70).

In contrast to the steady-state notion of engineering resilience, the third approach to resilience emphasizes adaptation, learning, and change in the so-called socio-ecological system, which encompasses interrelated and interconnected social and natural phenomena forming a system. This approach starts from the systemic resilience thinking of ecology, linking it to social phenomena to explain resilience in the social sciences (Aldunce et al., 2015; Brown, 2016; Cooke et al., 2016; Turner, 2014). The recognition of multiple stable states in ecological resilience rather than a single equilibrium "offered new directions and analyses, involving non-linear relationships, uncertainty, and shifting or multiple boundaries" (Brown, 2016:72), along with the history of disturbance and spatial heterogeneity, etc. Furthermore, the complexity of the ecological response to disturbance and change, whether of anthropogenic origin or not, broadened ecologists' understanding of the complexity and dynamics of ecological systems (Turner, 2014:617). This made ecological resilience more appropriate when studying the resilience of social phenomena characterized by constant dynamics, continuous learning, and adaptation (Mackinnon & Derickson, 2012:256).

The concept of resilience thus evolved in the social sciences, with political ecology, development economics, and environmental studies applied in studies of disasters in socio-ecological systems associated with social vulnerability and natural disaster management and reduction (Brown, 2016). In the socio-ecological discourse in disaster management studies, resilience is mainly described as "the 'capacity' of an actor, individual, community, social unit, organization, society or system to absorb, recover, cope, 'bounce back', mitigate, withstand or resist the impacts of hazards" (Aldunce et al., 2015:11). Therefore, the unit of analysis in socio-ecological resilience, although it may have different geographic contexts/scales, must be characterized by human interaction with the biophysical component or socio-environmental phenomena.

As a way to promote sustainable development and address challenges such as natural disasters resulting from climate change, these three resilience discourses are currently central to political, economic, and social discourses and to the agendas of major pro-environmental organizations worldwide. To cite examples of such organizations, there are the United Nations for Disaster Risk Reduction (UNDRR), the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), and the Millennium Assessment (MA) (Brown, 2016; IPCC, 2007, 2014; Turnhout et al., 2016; UNDRR, 2009, 2022). Promoting resilience has also become part of the agendas of major world economic organizations, such as the International Monetary Fund (IMF) and World Bank, and of various research institutions, universities, and states of the world, in both the Global North and Global South (Brown, 2016; Johnstone & Newell, 2018; Turnhout et al., 2016).

4.1.2. Conservative and systems thinking: two criticisms of resilience

Within the context of the evolution of applications of the resilience concept, criticisms have been raised about how the concept of resilience, with its roots in ecological systems thinking, could be applied in the social sciences, for analysing socio-environmental phenomena such as social development and human relations. One criticism raised is that "the concept of resilience, derived from ecology and systems theory, is conservative when applied to the social sphere, referring to the stability of a system against interference" (Mackinnon & Derickson, 2012:254). This criticism may be aligned with Olsson et al. (2015), who argued that the concept of resilience in social sciences is ambiguous, since transformation is seen as crucial to maintaining resilience. The following quotation illustrates their point about the ambiguity between transformation and maintenance: "The very dynamics between periods of abrupt and gradual change and the capacity to adapt and transform for persistence are at the core of the resilience of social-ecological systems" (Folke et al., 2010, cited by Olsson et al., 2015:11).

In response to this criticism, Brown (2016:20) pointed out that socio-ecological resilience "is not about predicting outcomes, but about building capacity, primarily adaptive capacity to deal with unknown futures". Furthermore, the criticism is outdated, as Holling (1973) assumed that, in the face of external disturbances, resilient systems can absorb changes and still persist, allowing other or new paths of analysis involving non-linear relationships, the possibility of changes, uncertainty, and multiple boundaries (Brown, 2016; Mackinnon & Derickson, 2012). This dynamic in the resilience analysis is what characterizes resilience in the social sciences, which "adds to resilience scholarship in a number of key ways and provides new insights into how resilience can be applied to discussions of global change and international development by introducing some of these issues – central to the field of development studies" (Brown, 2016:13).

Another criticism concerns defining the limits of the system in social sciences. System boundaries are universally recognized across disciplines, as they depend on the assumption that there is a certain set of entities that characterize them, nevertheless, "in the natural sciences, a certain set of entities is more accepted than in the social sciences" (Olsson et al., 2015:4). For resilience thinkers, the unit of analysis or the organizational scale of inquiry is the system (Turner, 2014:620). For example, in Luhmann's (2008, 2010) theory of systems, the environment (e.g., the ecosystem) "can never become part of society, and society can never become part of the environment" (Olsson et al., 2015). These criticisms question how ecological and systemic thinking about resilience in the natural sciences can incorporate social phenomena and help us understand the dynamics of social systems (Brown, 2016:12). For Olsson et al. (2015:4), "it is tempting to downplay the conceptual requirements of systems to make resilience applicable to social phenomena, but that would be a clear example of blurring the concept of resilience, which should be avoided because it would result in a less scientific concept".

However, according to Brown (2016) and Cooke et al. (2016), it is more important to understand the determinants of resilience in different geographical contexts/scales when analysing resilience, i.e., complex systems that range in scale from cells to ecosystems to societies, than to try to limit resilience thinking to single, predetermined patterns and expected outcomes. To address Olsson et al.'s (2015) criticism, that applying resilience to social phenomena would minimize the conceptual requirements of systems, and Luhmann's (2008, 2010) position that the social is not connected to the ecological to the degree of conceiving a socio-ecological system, Cooke et al. (2016) demonstrated the opposite through citing the example of dwelling. Cooke et al. (2016), in their study "Dwelling in the Biosphere: Exploring an Embodied Human–Environment Connection in Resilience Thinking", presented the example of dwelling, where human coexistence with the biosphere is clear. Cooke et al. sought to prove with evidence the unequivocal existence of a unit of analysis or study for socio-ecological resilience – i.e., the socio-ecological system – by demonstrating that dwelling is the local manifestation of humans' direct involvement with their everyday environment. "Dwelling can help to make us more conscious of the myriad ways in which we are already connected through time and space" (Cooke et al., 2016:839). Although dwelling occurs on the local scale, it is possible to see how a human engages with the biosphere by choosing a dwelling place on fertile land near a river, the position in which he places his house relative to the river, the arrangement of the cropping and grazing areas, the trees and fruit trees in the yard, the vegetation, and other domestic arrangements. Furthermore, in the backyard of the dwelling place, insects, rodents, and birds may come to benefit from cereals planted or spread in the sun to dry. This interaction between humans and nature through dwelling provides livelihood opportunities, joy, and meaning in everyday life.

All this interaction between humans and the environment (e.g., ecosystems) illustrates the natural character of the human as part of a socio-ecological system. Brown (2016), relying on Walker and Salt's (2006) explanation, clarified that "social-ecological systems have structures and functions that cover a wide range of spatial and temporal scales. Structures and processes are linked across scales, and these interactions can occur both bottom-up and top-down" (Walker & Salt, 2006, cited by Brown, 2016:76). Therefore, Brown (2016:76) argued that "we cannot understand the dynamics of change at any one scale without considering what happens at other scales", precisely due to their interconnection that influences and often guarantees the functioning of other scales (Brown, 2016; Cooke et al., 2016). To exemplify, "an assemblage of individual plants makes up a woodland or forest system, but each plant or each tree has a set of insects, fungi and bird species associated with it, each has its own dynamic, but each is linked" (Brown, 2016:76). The same happens with dwelling, which is circumscribed in a place or geographic space, which has its own dynamics in the human–environment relationship, but is interconnected with the area or the city in which it is inserted, which is a socio-ecological system on a larger scale with more complex socio-spatial and temporal dynamics.

Although socio-ecological systems are complex and have structures and functions that cover a wide range of spatial and temporal scales, these relationships illustrate and prove, at these different scales, the human connection to the biosphere. For example, bio-geographic studies demonstrate that human behaviour in terms of the exploitation of natural resources for centuries has caused global environmental problems due to deforestation, the extraction of water resources, the extirpation of fauna, etc. At the same time, with the development of concern for conservation, it has been observed that humans have managed parks and reserves in sustainable ways. In these areas, technicians (i.e., humans) from different areas have worked hard to safeguard the health of animals and vegetation, and at the same time, this wildlife coexists with eco-tourists. Therefore, "the conversation turns to exploring how we can foster, augment or dwell in the biosphere in a way that recognizes historical and cultural contingency, and with greater care for the nonhumans with which we dwell" (Cooke et al., 2016:839).

Thus, this interrelationship between humans and the natural environment, involving various functions, processes, and scales (Brown, 2016:76), constitutes an inherently good basis for constructive involvement in promoting or increasing the resilience of the socio-ecological system. In fact, "our current biosphere relationship may be problematic but our inextricable connection to it cannot be severed" (Cooke et al., 2016:839). Thus, in human–environment relations (e.g., human–river–extreme climate/flood) in the place of residence (i.e., the city), the concern is not whether there is a systemic interconnection, because there is. This theorization of the socio-ecological system by Cooke et al. (2016) with Brown's (2016) thought, demonstrates the existence of a systemic unit of analysis or organizational scale of investigation for socio-ecological resilience, which can be of different geographic, or space/time, scales. This system is marked by the relationship between humans (e.g., social actors and social structures) and the environment (both natural and built), and could be affected by disastrous events such as floods. Therefore, the concern should be how this affects daily lives and livelihoods, and what can be done to reduce flood risks, improve living conditions, and improve environmental functioning, all of which are at the core of this thesis.

4.1.3. Socio-ecological resilience and disaster risk management

Criticisms of the scientific leap in the use of the concept of resilience, from ecology to social ecology, have spurred scientific debate that has enhanced and refined the domain and applicability of the concept in theoretical and practical terms in the management of natural disaster risks. It is clear that, "inspired by a systemic conceptualisation of resilience and especially of complex adaptive systems, resilience has moved from the core idea of 'resisting and recovering' [from traditional ecology] into 'adapting'; and from 'stability' to 'change'" (Aldunce et al., 2015:3) of the socio-ecological system. Socio-ecological resilience opens up opportunities for improvement and innovation, qualities that suggest improved mitigation of and adaptability to natural disasters in a changing climate, encompassing diverse strategies that can be used at the individual, community, urban planning, and societal levels (Brown, 2016).

According to Brown (2016:102), in disaster risk management, vulnerability and resilience are properties of a socio-ecological system, as it is in this human–environment interaction that disastrous events occur, generating hazards and risks, and society must cope with them by promoting resilience. More specifically, socio-ecological resilience thinking provides a more integrated and dynamic systems approach that helps us understand hazards, whether individually, in communities, in urban areas, or in society at large. The most important contribution of the socio-ecological systems theorizations of Cooke et al. (2016), with the dwelling illustration, and of Brown's (2016) explanations of resilience, risk, and vulnerability for urban and community socio-ecological resilience is that they provide a suitable framework for analysing, interpreting, and responding to natural disasters. This framework for analysing and coping with disasters in communities and urban socio-ecological systems must be approached "in the context of socio-nature systems, recognizing the complexity of coupled socio-nature environments and a systemic approach to disaster management" (Aldunce et al., 2015:2). Above all, in the socio-ecological resilience approach to natural disasters, the system is seen as dynamic, working in the face of different kinds of change, including short- or long-term, and fast or slow changes (Brown, 2016). Thus, in the socio-ecological system, the socio-economic dynamic is marked by the social transformations that take place, reflected in the forms of land occupation and use of local natural resources that are the fruit of the individual and collective actions of communities, institutions, and social groups over time. In turn, nature and its natural phenomena, such as floods, droughts, and earthquakes, influence how humanity appropriates local natural resources, such as land and natural water sources, in turn influencing local socio-economic dynamics. Therefore, social and biophysical vulnerability elements relate to each other and produce a place's overall vulnerability and risk, to which socio-ecological resilience seeks to respond (Cutter et al., 2000).

The resilience approach benefits immensely from vulnerability and risk studies, and especially from analyses that highlight the biophysical and social aspects of vulnerability and its multiple, often interconnected causes (Brown, 2016:103). This means that when addressing resilience to natural disasters, such as urban floods, it is essential to consider both biophysical and social factors that influence exposure and the capacity to respond or cope with the stress caused by the disastrous event. These factors or constraints can be the location of the city in a flood plain, characteristics of the communities, the political or territorial management structures, the existing financial, and technical conditions, among others (Cutter et al., 2000; Vitale, 2020). Here learning and adapting are key aspects in reviewing the capacity of social actor and the structures of organizations associated with disaster risk management, to batter address flood resilience (Aldunce et al., 2015:11). Socio-ecological resilience is also characterized by anticipation: it "includes pre-event measures to prevent hazard-related damage and losses and post-event strategies to cope with and minimize disaster impacts" (Cutter et al., 2008:600). Thus, in promoting urban resilience to floods, one relevant strategy for urban planning and management (e.g., relevant sectors and experts) and community resilience building is to use mitigation techniques and resources as pre-event measures to prevent hazard-related damage and losses, minimizing disaster impacts. Furthermore, the planning and management of measures, actions, and post-event strategies to increase the adaptive capacity may increase a system's, community's, or society's resilience to future hazards (Aldunce et al., 2015; Cutter, 2008).

According to Brown (2016), transformability can also be a key aspect of resources. This is the essence of socio-ecological resilience, with resilience being defined as going beyond the mere capacity to endure, absorb, and remain in the same state; rather, it also includes self-reorganizing and being able to build and increase learning and adaptive capacity in response to crises – all fundamental aspects of analysing resilience to urban flooding. In addition, the promotion or enhancement of resilience to natural disaster risk events can be done considering the entire affected area or can be developed by studying particular aspects. For example, regarding urban flooding, the flood resilience approach can be applied considering the entire city and aspects of flood resilience, or addressing aspects such as socio-economic resilience, the resilience of hydraulic infrastructures, the agricultural activity practiced, electrical systems, or even local ecological ecosystems and community resilience (Mugume et al., 2015).

4.2. Actors, structures, and agency

In an urban socio-ecological system, which is the result of human–biophysical interaction, social actors and structures play a central role, through their agency, developing mitigation and adaptation strategies, measures, and actions for building or promoting flood resilience. Furthermore, the promotion of resilience to urban flooding proves the interrelationship between the human and biophysical environments, considering floods as generally natural phenomena whose impacts are managed by individuals, communities, and institutions (Brown, 2016; Cooke et al., 2016). The theori of actors, structures, and agency are relevant to social science research, as they provide conceptions of the nature of human social activity and of human agent behaviour in specific social spheres across time-space. What are social actors and structures? What is the role of agency in the performance of social actors and structures?

In structuration theory, actors or social actors are all human beings who are "highly 'learned' in respect of knowledge which they possess, and apply, in the production and reproduction of day-to-day social encounters [and] situations of social life" (Giddens, 1984:22). The social actor inserts and conceives him/herself in certain social realities, or in certain historical and cultural contexts of which the structures are part, where the actor expresses his/her knowledge, domain, and technical procedure for "doing" daily social activity (Carolan, 2005; Giddens, 1984; Modell, 2020). "Such knowledge does not specify all the situations which an actor might meet with, nor could it do so; rather, it provides for the generalized capacity to respond to and influence an indeterminate range of social circumstances" (Giddens, 1984:22). The action of social actors is a continuous process in which the intentional and reflective follow-up that individuals maintain over their actions throughout their day-to-day lives is fundamental to achieving their objectives (Giddens, 1984). Through their intentional actions, individuals can positively influence actions, for example, to promote resilience, and this in turn contributes to the achievement of their objectives, such as safety for themselves and their households in relation to possible floods. Therefore, an actor's capacity to respond to and influence an indeterminate range of social circumstances is, in itself, the human being's ability to exercise the agency of production, reproduction, and social transformation (Giddens, 1984; Modell, 2020; Ward, 2018).

Giddens (1984:23) distinguishes "'structure' as a generic term from 'structures' in the plural and both from the 'structural properties of social systems'". In structuration theory, the structure is considered to comprise established rules and mobilized resources recursively implicated in, influencing, or determining social reproduction (Giddens, 1984), meaning that "structure is the environment within which rules and resources exist, which determines social action" (Ward, 2018:247). Rules and resources are fundamental to the structure's constitution and functioning. Therefore, for social reproduction, structures extract resources from the biophysical environment and protect other resources for different uses, revealing the systemic human–biophysical interrelationship (Cooke et al., 2016). The above definitions of "structure" share the idea that social structures are constituted by sets of properties that are socially constructed and reconstructed based on rules and resources through historical processes of production, reproduction, and transformation involved in institutions (Giddens, 1984; Modell, 2020). Institutions are "the most enduring features of social life" (Giddens, 1984:24). Thus, institutions are the institutionalized characteristics or properties of social systems that give solidity over time and space to social structures in which social actors play their roles of production, reproduction, and transformation (Giddens, 1984).

According to Giddens (1984:10), "agency refers to doing". Ward (2018:247) defined agency as the "ability of actors to act freely within their own right, which creates structure". Furthermore, agency is a distinctly human phenomenon conditioned by the existing social structures (Modell, 2020:622). "It is always the case that the day-to-day activity of social actors draws upon and reproduces structural features of wider social systems" (Giddens, 1984:24), meaning that the rules and resources condition the agency of actors, but in turn, the agency of actors or the actions of production, reproduction, and transformation create or shape structures or institutions inserted in the social system (Giddens, 1984; Modell, 2020; Ward, 2018). Agency does not refer to the intentions that people have when doing things, but to their ability to do those things in the first place, as agency implies power and having an effect on existing social structures and social systems. Therefore, agency refers to "events of which an individual is the perpetrator, in the sense that the individual could, at any phase in a given sequence of conduct, have acted differently" (Giddens, 1984:9), thereby affecting, possibly in a different way, the existing social structures and social systems.

Agency as the capacity to act includes the human reflexive dimension that occurs in the interaction among human beings as well as between humans and their environment, comprising the natural environment as well as material, technical, financial, and other elements and thus producing meaning in the form of structures (Callon, 2005:4). Therefore, structure is an order of social production and reproduction based on transforming relationships. This means that "social systems, as reproduced social practices, do not have 'structures' but rather exhibit 'structural properties' and that structure exists, as time-space presence, only in its instantiations in such practices and as memory traces orienting the conduct of knowledgeable human agents" (Giddens, 1984:17). Thus, all human beings, as social actors, have knowledge and discernment, and seek to apply them wisely in their day-to-day activities in social production and reproduction, or in social encounters. Most of the knowledge used to address the challenges of everyday social life is practical and not theoretical (Giddens, 1984). Structuration theory, goes further by placing the human activity of social production and reproduction in its cultural and historical contexts and processes, implying that future opportunities arise from the ongoing and sometimes unpredictable relationship and interaction between agency and structure (MacKay & Tambeau, 2013:684). This unpredictable interaction sometimes arises from shocks from natural events, such as flooding, requiring social actors and structures to wield their agency, adapting rules and building capacity to develop mitigation and adaptation measures.

The awareness of social rules, in their historical and cultural contexts, is expressed first of all in the practical awareness or consciousness of the day-to-day lives of social actors, and it is this knowledge or acknowledgment that particularly characterizes human agents (Giddens, 1984). However, actors and their purposes are generally prior to and particularly autonomous in relation to the impositions and limits of existing institutional or social structure rules "that constrain and empower them" (Meyer, 2010:2). Therefore, in this actor–action relationship, society and its structures are also products of individual intentions and purposes. However, the locations of actors and communities in different sectors of society or regions of broader social systems strongly influence their habitual behaviour or conduct, their integration into social systems, and consequently their impact on social totalities (Giddens, 1984). Structures are manifested in the formal and more informal norms that guide daily social production and reproduction, that reinforce the socialization of human beings in specific groups, such as organizational hierarchies and stratifications of social classes, which offer multiple levels of analysis in social research (Modell, 2020:622).

It is true that structures or institutions have the power to enable or constrain agents or social action; however, through repetitive actions and interaction in human agency, humans as cultural, historical, and reflective beings, have the ability to alter structure (Giddens, 1984; Ward, 2018). According to Meyer (2010:15), actors and institutions "so created now with the standing of agentic actors commonly act on behalf of the great principles that empower their agency. Far from ordinary self-interest, they often act as mobilized others, creating expanded versions of actorhood". Their actions may sustain existing structures or change the institutional environment (MacKay & Tambeau, 2013; Ward, 2018); however, "we should not conceive of the structures of domination built into social institutions as in some way grinding out 'docile bodies' who behave like the automata suggested by objectivist social science" (Giddens, 1984:16). Rather, the emancipatory and transformative courses of action of actors and institutions of social production and reproduction that emerge within organizations or social structures can generate new patterns of rules that can be stabilized or established and adopted over time, generating new forms of social structures and social transformations in the social system (Modell, 2020:623). These transformations occur in the specific social sphere through time-space, the space of human–biophysical interrelations (i.e., the socio-ecological system), embedded with transformations, adaptations, and changes that shape the socio-cultural-biophysical environment, communities, institutions, and cities over time (Brown, 2016; Cooke et al., 2016; Lee, 2022; O'Donnell et al., 2019; Xu et al., 2021).

According to Giddens (1984:16), "power within social systems which enjoy some continuity over time and space presumes regularized relations of autonomy and dependence between actors or collectivities in contexts of social interaction". Conversely, actors are from distinct structures/institutions, and their capacity to act and the impact of their actions are influenced by the specific positions they occupy in these structures, the resources they control, their capacity to monitor what they are doing and its effects, and, of course, the specific actions that they perform (Jessop, 2001). "But all forms of dependence offer some resources whereby those who are subordinate can influence the activities of their superiors" (Giddens, 1984:16), which means that the social actors and social institutions whose positions in the social system are inferior can influence the course of the actions of production and social reproduction through their capacity for agency, or by influencing the decisions and actions of the actors and/or institutions positioned at the top.

4.3. The analytical framework of the study

The analytical framework of this study is at the heart of this research, and it was developed in line with a socio-ecological resilience approach. It serves as an instrument that guides the analysis of the empirical data as well as framing the findings (see Figure 4.1).

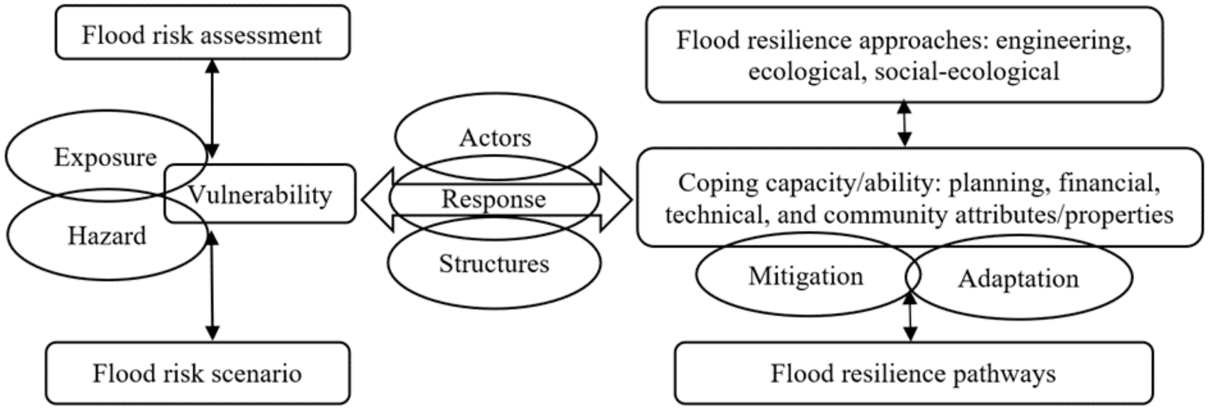

Figure 4.1: Analytical framework (source: author's adaptation based on the literature).

The flood risk assessment, which includes the assessment of exposure, hazard, and vulnerability, and the analysis of resilience to floods in Matola, which includes the responsive capacity/ability of local actors and structures, are important components that make up the analytical framework of this study. As can be seen in Figure 4.1, assessing the risk of flooding is one of the primary stages of the research, as it will provide detailed results on the distribution of the different levels of flood risk. In this study, flood risk is assessed through hydrological modelling, considering the 2000 floods, the most devastating floods of recent decades but also making projections for the future. Assessing present and future flood risk through flood modelling allows for predicting flood conditions as well as their impact in Matola, i.e., the potential losses that flooding may cause for people, property, and the environment.

To determine the flood risk, exposure assessment is included as part of the process, which provides the extent, quantity, and quality of the property, assets, infrastructure, and people under threat from the flood event. Additional fundamental information about the flood event is its intensity, duration, velocity, and depth, which as a whole represent the flood hazard. In this case, the hazard is the main trigger of the occurrence of flood risk. In turn, the degrees of loss due to floods or potential risks are determined by vulnerability, which is expressed by social/human conditions as technical, and financial resources as well as the capacity of actors such as urban planners and community members to act to respond to the flood at the municipal, community, household, and individual levels. The expression of vulnerability also includes natural, physical, and biophysical characteristics, such as the topography, soils, local climate, local water resources, and diverse animal and plant ecosystems and their functionalities. These influence the degree of impact that the floods have on the territory. For example, if floods occur on sloping or very steep terrain without vegetation cover (i.e., biophysical characteristics), this increases the velocity of the floodwater, causing more dragging of people and goods and more erosion, but faster water evacuation. If the floods occur on flat land, however, the velocity of the water is slower and there may be a risk of protracted flooding, contributing to the temporary or permanent abandonment of the flooded areas by the population.

After the flood risk assessment, this study analyses, interprets, and explains the strategies, measures and actions to promote resilience to urban floods, with a focus on urban planners and members of local communities in the socio-economic context in which they are inserted. Paper II in particular explores and analyses the mitigation actions the urban planners adopted during the major flood event of 2000, what flood adaptation strategies for increased flood resilience (i.e., ecological, engineering, and socio-ecological approaches) they developed after that flood event, and the contribution of urban planning to building flood resilience in Matola. Paper III addresses how community members adapt and strive for resilience, addressing what actions and measures communities in Matola have developed to cope with urban flooding since 2000 in light of the dimensions of community resilience (i.e., the financial, physical, environmental, social capital, and institutional and organizational dimensions) highlighted in chapter 3.

Urban space is socio-ecologically produced in interplay between social relations and environmental/biophysical factors. Society comprises a set of structures, such as institutionalized practices, norms, values, and rules with its own characteristics, properties, and material effects in time and space in the form of urban spaces in an interconnected relationship and continuous interaction between the human and the biophysical environment. By positioning urban spaces in their cultural and historical contexts, in unpredictable recursive relationships among actors, social structures, and the biophysical environment, resilience to urban floods is eminently socio-ecological. For urban planning and development aimed at promoting resilience to urban floods, in addition to considering the needs of housing, education, and transport infrastructures, among others, it is essential to include the biophysical component, or natural green areas and natural water courses in the plans, as part of the urban fabric. This study analyses the promotion of resilience to floods in Matola considering local regulations, the technical and financial capacity of urban planners, and the characteristics of communities and their dealing with the natural environment.

Thus, in this study, flood resilience is defined as the capability and ability of socio-ecological systems to cope, withstand, or resist, and absorb the impacts of flood hazards, recover, and change. The socio-ecological system is highlighted in the above definition, since the risk of flooding generally, particularly in urban areas, affects the social and biophysical components in an area, including the river catchment, people, infrastructures, and assets. Therefore, the actions and measures that could be developed to promote resilience, that is, to reduce or limit flood hazards, are eminently socio-ecological, as they aim to adapt the biophysical and socio-economic environment to floods.

Considering resilience to urban floods as eminently socio-ecological does not mean that the ecological or engineering approaches cannot be developed in the context of promoting resilience to urban floods. On the contrary, as previous studies have suggested, ecological or engineering approaches ought to be developed in support of the socio-ecological approach. To build resilience to urban flooding, there is also a need to value and include the biophysical component, that is, natural green spaces and natural watercourses, which in itself is an indication of the relevance of ecosystems – i.e., ecological resilience. In addition to playing their natural role as watercourses and water reservoirs in the rainy or flooding season, for the maintenance and preservation of plant and animal life (e.g., mangroves), these natural spaces also play their role as water reservoirs used in various human activities, providing livelihood opportunities, joy, and meaning in everyday life. In turn, the engineering approach is also one of the paths towards urban flood resilience, as urban infrastructures, such as drainage systems and dams, can also be designed and built to control and channel water.

With inspiration from previous studies of urban planning and management processes focused on the adoption of flood mitigation and adaptation measures, and with the help of the analytical framework, this study focuses on how have flood hazards and risks been distributed in Matola and what mitigations and adaptations strategies, measures, and actions urban planners and communities used to promote flood resilience in Matola during and after 2000 floods. This analysis will help reveal which resilience discourses and approaches correspond to those measures and strategies taken in Matola. Furthermore, this study is interested in studying how different political interests or demands, the knowledge of urban planners, and community knowledge based on local solutions in different community groups of flood victims all contributed to promoting resilience in Matola.

5. CONTEXT OF URBAN DEVELOPMENT AND MANAGEMENT IN MOZAMBIQUE

This chapter aims to position the study area within the context of urban development and municipal urban management facing the challenge of promoting resilience to floods. The chapter is divided into sections, presenting the origin of the colonial city, post-independence urban development, and the municipalization process in Mozambique. The legal framework of urban flood management in Mozambique and the challenges facing municipal urban planning and management are then presented.

5.1. The colonial growth cities

The driving force of the emergence of the first cities in what today is Mozambique was the international trade via the commercial warehouses of, for example, Sofala, dating from 1505, and Ilha de Moçambique, dating from 1507, along the East African coast. In these commercial warehouses, exchanges (e.g., in ivory, gold, animal products, and slaves) were made between African peoples and foreign merchants, especially Arabs and Indians, between the 9th and 15th centuries (Baia, 2011; Ribeiro, 2019).

With the colonial occupation and domination of current Mozambican territory, there was an increase in the construction of small towns with urban features at certain militarily strategic points, mainly along the coast, for the control, domination, exploitation, and circulation of goods. The rise of large, modern urban centres in Africa began with the effective colonial occupation of Africa after the Berlin Conference of 15 November 1884 and 26 February 1885, which aimed to organize and regulate the occupation of Africa by the colonial powers, and resulted in a division that did not respect either regional history or the ethnic or even family relations of the peoples of the continent (Baia, 2011; Chagastelles, 2008).

In Mozambique, the growth of colonial cities became more noticeable from the 1940s until national independence in 1975 (Araújo, 2003; Ribeiro, 2019). In this way, the urban spaces inherited in 1975 from the Portuguese settlers are the result of external factors in which the concentration of economic activities that generated urban development, was decided on and imposed according to external interests, particularly colonial ones. The indigenous African population was always marginalized, occupying the periphery and under precarious living conditions (Araújo, 2003; Vicente, 2014).

The colonial cities were characterized by two urban areas: the so-called "cement city" where white people lived was planned, having vertical development, infrastructure, and services; in contrast, the so-called "city of reeds" (caniço) where black people lived was suburban, horizontal, unplanned, and spontaneously built, used precarious architecture and materials such as stakes, clay, and reeds, and lacked the infrastructure and basic services available to the public in the "cement city" (Araújo, 2003; Maloa, 2019; Ribeiro, 2019).

Matola, as a colonial city, also emerged in response to capitalist needs, but with its own characteristics. It emerged to fulfil the needs of the colonial power, for example, for military and/or administrative control and the export of raw materials, generally from the interior through the ports of Matola and Maputo. Matola grew and developed as a dormitory city, built to house employees of the industries that arose near the port of Matola, in what is known as the Matola industrial park (Araújo, 2003). This process implied the planning of a "cement city" that would satisfy demand for the typically urban needs of the inhabitants, not only for housing, but also for the supply of water, electricity, transportation, communication, education, health services, security, entertainment in cinemas, nightclubs, restaurants, social centres, etc. As in all Mozambican cities, the process of constructing Matola transplanted models and perceptions of the organization of urban space from the realities of colonial metropolises, implanting them in the colonial territory that is now Matola, where they have remained to this day (Araújo, 2003; Baia, 2011). However, Matola, like other colonial cities, also had unplanned areas of precarious housing since the colonial era, inhabited by the African or indigenous population.

5.2. Post-independence urban development

With Mozambique's achievement of national independence in 1975, the colonial "cement cities" were handed over as an inheritance to the workers and peasants who once lived in the countryside and in precarious caniço or indigenous neighbourhoods. These cities were the result of the capitalist production mode introduced in Mozambique by force of arms and colonial domination that over time resulted in urban growth. The African or indigenous population that inherited the cities also participated in the process of developing these cities throughout colonial times, as slaves or cheap labour (Araújo, 2003).

The post-independence Mozambican government established an urban governance and management system of "Executive Councils", organs established for building management and urban planning, which prevailed until the establishment of the municipalities in 1997. However, for several reasons the Executive Councils had great difficulty guaranteeing sustainable urban development and social well-being in cities. The 1970s, 1980s, and 1990s were characterized by a conjuncture of several adverse factors, such as the Mozambican War of Independence, the post-independence civil war from in 1975 to 1992, and calamities such as droughts and floods that made the countryside repulsive and urban spaces attractive. This resulted in an urban implosion in which much of the urban growth did not occur due to the occupation of space on urban peripheries, but rather because the peripheries advanced towards the city centres, giving them characteristics of suburbanization and "ruralisation" (Araújo, 2003; Baia, 2011). This centripetal aspect of the urbanization process resulted in areas of caniço neighbourhoods invading almost all urban green spaces around city centres. These comprised small, informal clusters of housing, outbuildings, and garages, representing habitable space for several families. Furthermore, many of the new occupants were not yet aware of the urban stance towards using houses and other urban infrastructure abandoned by settlers in 1975, leading to deterioration and degradation of the urban environment due to misuse.

Another aspect that affected Mozambican cities such as Matola shortly after independence was the lack of specialists in urban planning and development. The need for them was urgent, since the colonial architects and urban planners had all been expelled, and the few literate people, once servants, were appointed specialists by the new post-independence government, but without any specialized skills or knowledge. This lack of specialists led the post-independence Mozambican government to create institutions dedicated solely to managing the inherited urban infrastructure, such as the State Property Administration. These institutions were unable to regulate, plan, and control the cities effectively with a view to circumventing the growing urban problems due to informal development and the deterioration of the urban infrastructure and environment.

After Mozambique's national independence, access to and use of the land was based on Law no. 6/79 of 3 July 1979 (Moçambique, Lei nº 6/79) and the associated regulation approved by Decree no. 16/87 of 15 July 1987 (Moçambique, Decreto nº 16/87). The land law included rules related to access to and use of urban land. Associated with the need to regulate land use at a national level, administrative divisions were decreed in 1986, which delimited urban and rural areas throughout the national territory. Because of the need to restructure the administrative machinery and to improve urban services and development in Mozambican cities, several programmes were instituted with the support of the World Bank and UN-Habitat, which gave some institutional capacity to the Executive Councils. One of these programmes was the Project for the Restructuring of Local Bodies (PROL). It started in 1991 in the area of urban housing development and was supported by the World Bank, carrying out activities such as urban structure planning, cartography, and the improvement of urban periphery areas. Another was the Urban and Housing Development National Program (PNDUH), which started in 1993 and concluded in 1998, financed by the government with technical assistance from the UNDP/UN-Habitat. The PNDUH supported the Executive Councils in creating technical files and a database, and in creating a documentation centre for the urban and housing development sector (UN-Habitat, 2018:133). Although these programmes created a technical and institutional basis for urban planning, management, and development in the cities, they were unable to solve the problems of informal settlements – old and new caniço and "wood and zinc" neighbourhoods.

5.3. Municipalization

The first attempt to create municipalities began with the formulation of a strategy for the introduction of decentralized local governance by the Ministry of State Administration, which the government approved in 1994, in Law no. 3/94, the Municipal Districts Institutional Framework Law (Moçambique, Lei nº 3/94). This law provided for the gradual introduction of statutorily elected municipal councils throughout the national territory, eventually including all 23 cities and 121 districts. The main objective of the municipalization was to decentralize the management of cities, from being managed by the central government, represented by the Executive Council in each city, to being governed by locally elected municipal governments with powers of urban planning, management, and development.

Law 3/94 was replaced in 1997, when the Basic Law of Municipalities was approved (Moçambique, Lei n° 2/97). Law no. 2/97 gives the Municipal Councils the administrative, financial, and property autonomy and responsibility for the urban planning and management of the municipal territorial areas. In 2018, Law no. 6/2018 was enacted, amending Law no. 2/97, which establishes the legal framework that confers governance powers on the municipal authorities, and in Article 9 (1) gives administrative, financial, and patrimonial autonomy to the municipal authorities (Moçambique, Lei nº 6/2018).

The National Land Policy and Implementation Strategy (Moçambique, Resolução nº 10/95) was a legislative package with implications for land management and planning in Mozambique. Article 3 of the 1997 Land Law (Moçambique, Lei nº 19/97) states that "the land is state property and cannot be sold or in any way alienated, mortgaged or pledged". Through the Land Law Regulation (Moçambique, Decreto nº 66/98), the previous Decree no. 16/87 was repealed. Article 2 of the Land Law Regulation stipulates that this regulation "applies to areas not covered by areas under the jurisdiction of Municipalities that have Municipal Registration Services" (Moçambique, Decreto nº 66/98, translated from Portuguese). In turn, the urban territorial management system was established through the Urban Soil Regulation in 2006 (Moçambique, Decreto nº 60/2006). Article 2 of Decree no. 60/2006 states that this regulation "applies to city and village areas legally existing and human settlements and population clusters organized by an urbanization plan" (translated from Portuguese). This regulation applies without exception to areas with an urbanized structure, including the municipalities.

In Mozambique, the National Spatial Planning Policy was approved in 2007, one goal of which is the "integration of spatial planning instruments into economic planning and the development of political-administrative territorial units at all levels" (MICOA, 2009:4, translated from Portuguese). Inspired by the National Spatial Planning Policy, the Law of Spatial Planning was approved in 2007. No. 1 of Article 6 states that: "1. It is the responsibility of the State and Local Authorities to promote, guide, coordinate and monitor the territorial planning in an articulated manner, within the scope of their attributions and the competences of the respective organs" (Moçambique, Lei nº 19/2007, translated from Portuguese). In addition, this responsibility should be undertaken in the public interest, with respect for the rights, freedoms, and guarantees of the citizens. According to the same law, the Territorial Management System comprises the national, provincial, district, autarchic, and municipal levels of intervention in the territory. As can be inferred from its national scope, it covers not only urban areas, but also rural ones.

On the other hand, the Regulation of the Spatial Planning Law, approved in 2008, determines what constitutes a national spatial planning instrument (Moçambique, Decreto nº 23/2008). First, the National Plan for Territorial Development (PNDT) is the instrument that defines and sets out the perspectives and general guidelines for the use of the entire national territory, and the priorities for national interventions. Second, there are the Special Spatial Planning Plans

(PEOT), which are the instruments that establish the parameters and conditions of use of the zones, with spatial, ecological, economic, and inter-provincial continuity. For territorial planning at the provincial level, there are the Provincial Plans of Territorial Development (PPDT), and at the district level, the District Land-Use Plans (PDUT), which define the norms and rules to be observed in the use of land and the use of its natural resources.

The Regulation of Spatial Planning defines the instruments of municipal territorial planning: the Plan of Urban Structure (PEU), the General Plan of Urbanization (PGU), the Partial Plan of Urbanization (PPU), and the Detail Plan (PP). The PEU is the instrument that establishes the spatial organization of the entire territory of the municipality. The PGU is the instrument that establishes the structure and zoning of the urban land in its entirety, considering the balance between the various urban uses and functions (Moçambique, Decreto nº 23/2008). Thus, the PEU and PGU have remedied a legislative gap that existed since the creation of the 33 municipalities in 1998. According to Law no. 2/97, the responsibility for urban land-use planning was transferred to the municipalities, to provide sustainable human infrastructure, services, and settlements, enabling the active participation of citizens in the construction of economic and social well-being and environmental protection (Moçambique, Lei n° 2/97). This responsibility is still advocated by Law no. 6/2018 (Moçambique, Lei nº 6/2018), which amends Law no. 2/97.

Article 9 of the new Law no. 6/2018 determines that "municipalities have a responsibility to ensure local economic and social development; the environment, basic sanitation, and quality of life; public supply; health; education; culture, leisure, and sport; local police; urbanization, construction, and housing" (Moçambique, Lei nº 6/2018, translated from Portuguese). The Regulation of the Spatial Planning Law also defines the Partial Urbanization Plan (PPU), which is the instrument that partially establishes the structure and zoning of the urban land. It also defines the Detail Plan (PP), the instrument that defines in detail the typology of occupation of any specific area of the urban centre, conceiving the conditions of buildings, layout, traffic routes, and characteristics of infrastructure networks and services (Moçambique, Decreto nº 23/2008). In addition to these basic laws, other complementary laws and decrees have been approved and published over time, intended to regulate and organize the functioning of the municipalities' technical and administrative services and their relationship with other public and private institutions.

5.4. Legal framework for urban flood management

With the occurrence of extreme natural phenomena such as extreme droughts in the 1990s and extreme floods, whose great benchmark was the flood of the year 2000, the Mozambican government set up new institutions and management plans to manage natural disasters, and to adopt and apply adaptation and/or mitigation measures in partnership with urban management institutions. Therefore, in addition to the legislative framework directly linked to urban land management, a set of instruments has been prepared by the Mozambican government to deal directly with the issues of climate change and natural disasters, with an emphasis on cyclical droughts, cyclones, and floods.

The technical and operational capacity of the National Institute of Meteorology (INAM) to provide early warning weather data on extreme events was strengthened. The operational capacity of the National Directorate of Water Resources Management (DNGRH) was also strengthened, to provide advanced data on the hydrological situation of the Mozambican watersheds. These two institutions began to cooperate closely with the newly created National Institute for Disaster Risk Management and Reduction (INGD) in 1999, in the Ministry for the Coordination of Environmental Action (MICOA), which has the function of monitoring and managing natural hazards. Over time, plans or strategies for disaster risk management were approved and improved, as presented below.

The Mozambican government approved the Vulnerability Assessment Climate Change and Adaptation Strategy in 2005, the Master Plan for the Prevention and Mitigation of Natural Disasters (PDPMCN) for 2006–2016 in 2006, the National Adaptation Program for Action in 2008, the National Climate Change Adaptation and Mitigation Strategy for 2013–2025 in 2012, and the Master Plan for Disaster Risk Reduction for 2017–2030 in 2017 (CM, 2017; MICOA, 2005, 2008, 2012). These plans have remained relevant over time for the development of measures and actions to mitigate and adapt to the effects of climate change in Mozambique. However, they have gradually been improved to better address new challenges, resulting in a new plan. In 2014, Law no. 15/2014, which establishes the legal regime for disaster management, was approved. This Law covers disaster prevention, mitigation of the destructive effects of disasters, development of relief and assistance actions, as well as reconstruction and recovery actions in affected areas (Moçambique, Lei nº 15/2014). All these instruments clearly prioritize the need to adopt measures and actions to adapt to and/or mitigate floods in urban planning, for example, via early warning systems, urban restructuring resettlement involving the elimination of informal settlements in risk areas, construction of drainage systems, and control of rainwater and marine intrusion, all intended to make cities more resilient. The institutions listed above work closely with the municipalities of the country both in providing data to support the planning action and in mitigating and/or adapting to flooding.

Associated with the above strategic plans is a set of rules on the management of various natural resources, to which territorial and urban planning must be adjusted. There is, for example, the Environmental Law, which, as stated in Article 2, “aims to define legal bases for the correct use and management of the environment and its components, to materialize a sustainable development system in the country” (Moçambique, Lei nº 20/97, translated from Portuguese). Furthermore, the Environmental Law stipulates in Article 30 that it is necessary to guarantee the participation of local communities in the management and use of natural resources, applying community knowledge and including community environmental inspection in coordination with government and local authorities. Another example is the Conservation Law (Moçambique, Lei nº 16/2014), which was amended by Law no. 5/2017 (Moçambique, Lei nº 5/2017) and regulated by Decree no. 89/2017, which establishes the basic principles and standards for the protection, conservation, restoration, and sustainable use of biological diversity in conservation areas, which are also found in urban spaces, as well as the framework of the integrated administration for the sustainable development of the country (Moçambique, Decreto nº 89/2017). Another fundamental law is the Water Law, which establishes the rules for the use of water resources, the treatment or use of watersheds, and the use of riverbanks and floodplains (Moçambique, Lei nº 16/91). This overview shows that there exists concern to develop the capacity to build resilience to floods in Mozambique, at least in theoretical, legislative, normative, and strategic plan terms, supporting urban planning and community actions intended to promote and increase resilience to natural disasters, including floods.

5.5. Challenges to municipal urban planning and management in Matola

Territorial and urban planning are considered key instruments for the occupation and use of land, natural resource extraction, territorial development, and sustainable urbanization. In 1997, municipalisation was institutionalized in Matola through the creation of the Municipal Council of the City of Matola, which has since assumed, among others, the task of planning, coordinating, and restructuring the city. In Matola, new luxury neighbourhoods and luxury condominiums occupied by financially powerful citizens have gradually appeared, obviously bringing a new image to the municipality. Due to this development, the municipality developed partial and detailed plans projecting new middle-class neighbourhoods, rezoning agricultural areas into residential areas, and creating new social and economic infrastructure. This difficult task is still being developed, in view of all the problems described in sections 5.2 and 5.3 and the problems of natural hazards, in particular floods.

Financial inability is one of the persistent challenges. Studies show that cities, particularly those in developing countries, currently lack sufficient funding and revenue sources to address climate change challenges, such as droughts, floods, cyclones, heavy rainfall, and rising sea levels, within the context of rapidly increasing urbanization (ICLEI, 2017). Indeed, the Mozambique National Report for the Third United Nations (UN) Conference on Housing and Sustainable Urban Development (Habitat III), 2016, points out that one of the factors affecting non-compliance with most urban development plans is insufficient financial resources (MOPHRH, 2016). In addition, governments of developing country cities, such as Matola, "demonstrate deficient capacity to mobilize, secure, and manage the financial resources needed to meet pressing urban infrastructure investment needs for resilient climate and sustainable urban development" (ICLEI, 2017:9).

Another challenge identified by the National Association of Municipalities of Mozambique and the World Bank is a lack of integrated planning capacity (to address finances, land use, socio-economic infrastructure, etc.) and poor organizational systems to elaborate on and realize urban plans. This poor planning capacity constitutes a serious constraint for Mozambican municipalities (ANAMM & WB, 2009:129) and has prevailed over the years. Since municipalization until around 2015 there was "poor technical capacity in most municipalities and lack of mastery of the procedures for the preparation of Territorial Planning Instruments (IOTs) contained in Territorial Planning Legislation" (MOPHRH, 2016:14).

This situation is aggravated by the absence of multi-level governance mechanisms that facilitate or enable access to long-term funding sources for subnational governments (ICLEI, 2017:9). The technical and political incapacity reported by the above authors/organizations is evidenced in Matola, as shown by insufficient harmonization in intra- and inter-institutional, political, and technical coordination in the implementation of actions for sustainable urban planning. For example, the drafting of the Matola Municipality Structure Plan in 2009 was interrupted due to a change of municipal political leaders, which eventually delayed the work of the Habitat Studies Centre (Andreatta & Magalhães, 2011:10–11). Moreover, of the partial plans elaborated on after this interruption, few were made official. In Mozambican municipalities, "less than 1% of the plans prepared were ratified and published in the Bulletin of the Republic" (MOPHRH, 2016:14). This demonstrates that over 99% of the existing plans are not formalized instruments for use in urban land management, following Article 13 in the Law of Spatial Planning (Moçambique, Lei nº 19/2007).

In addition, another very important challenge that explains the current form of land use in the City of Matola is the weakness in citizen involvement in decision-making, control, and benefits. According to Francisco (2007), participation is considered a way of exercising democracy through which people learn to elect, delegate, promote alternation in public and management positions, express their needs and views, and listen to others. It also allows people to make demands for accountability from those who represent communities concerning actions previously planned by mutual agreement. Participation enables "the debureaucratization of public agencies, forcing leaders to serve the community … it is a task that requires creativity, the formation of authentic community representatives" (Francisco, 2007:102, translated from Portuguese).

Regarding the involvement of different stakeholders in planning, Cornwall (2008:272), outlined the "ladder of participation" with seven degrees of participation, extending from the lowest to the highest: (i) Manipulative – representatives of the "people" are present in official councils, but they are not elected and do not have power, participation being simply pretence. (ii) Passive – people participate by being told what has been decided by external professionals or has already happened. (iii) Consultative – people participate by being consulted or by answering questions about problems and information controlled by external professionals, who are under no obligation to take on board people's views and do not grant them any role in decision-making. (iv) For material incentives – people participate by contributing resources, for example, fields and labour, in return for food, cash, or other material incentives, yet people have no stake in extending the use of technologies or practices when the incentives end. (v) Functional – people may participate by forming groups to meet predetermined objectives related to the project. Such involvement may be interactive and involve shared decision-making but tends to arise only after major decisions have already been made by external agents. This is used by external agencies to achieve project goals, especially reduced costs. (vi) Interactive – participation is seen as a right, not just the means to achieve project goals, and people participate in joint analysis and the development of action plans, forming or strengthening local institutions. (vii) Self-mobilization – people participate by taking initiatives independently of external institutions to change systems, which may or may not challenge existing distributions of wealth and power. They develop contacts with external institutions (e.g., governments and NGOs) for resources, technical advice, or the framework of needed support, but retain control over how the resources are used.

Participation in municipal governance in large municipalities in Mozambique, such as Matola, is fundamentally informative, i.e., intended to inform communities of municipal activities, and consultative, i.e., intended to seek opinions from communities about any activity that the municipality or a sector, such as urban planning, intends to carry out. In these informative or consultation meetings, community leaders are involved at the will of the president of the municipality (Nguenha, 2009), fulfilling Decree 51/2004 (Moçambique, Decreto nº 51/2004) and Ministerial Diploma 80/2004 of 14 May (Moçambique, Diploma ministerial n°. 80/2004). Despite that, "the media are the main conduit vehicle for sharing information on decisions taken with local communities" (Nguenha, 2009:14, translated from Portuguese), which shows that few people are engaging in participatory processes in municipal governance.

Therefore, considering the above degrees of participation outlined by Cornwall (2008), the informative or consultation meetings that have been happening in Matola are in fact a kind of bit engaging participation. To make matters worse, the major drawback of community consultations in local authorities such as those in Matola is that, although participation "gives citizens the possibility to express their needs and even proposals for solutions, the decisions that public managers make are not always based on such proposals" (Nguenha, 2009:15, translated from Portuguese). This means that community consultations do not ensure the effective participation of citizens or the fulfilment of their needs. These weaknesses that compromise the exercise of sustainable participatory urban planning extend, of course, to control over the municipal territory. This situation creates a fertile space for other challenges, such as an illegal land market due to increasing demand for urban space not satisfied by the municipal authorities.

In the green belts around major urban centres such as Maputo and Matola, the land market is therefore important, with high levels of informal price speculation for land acquisition, although the land formally belongs to the state and cannot be bought and sold (ANAMM & WB, 2009). This reality prevails today because "the speed with which territorial phenomena occur is much higher than the intervention capacity of entities responsible for urban development" (MOPHRH, 2016:14). These land market practices lead the needy people to opt for the cheaper spaces that are usually found in green and flood-prone areas, or these people do not buy land but simply occupy these areas to build their infrastructure. These structures for residential and commercial purposes are often precarious in the floodplains of Matola, "occupying more and more of the remaining, wet coastal protection areas, taking advantage of the scarce hypothetically free and available space, some based on stilts or piles and others using conventional material such as cement" (Neves, 2018:124, translated from Portuguese). This phenomenon dates back to the 2000 floods and still prevails today, occurring in the sight of local municipal authorities.

6. METHODOLOGY

This chapter presents the methodological approach that guided the research design used in this research, to achieve the aims outlined here. Furthermore, it presents the study area, the methods used in data collection, analysis, and presenting the results, as well as the ethical considerations and the limitations of the research.

6.1. Methodological approach

This study conceives of science as an ongoing process of transformation, continually or essentially dynamic, in an attempt to capture, penetrate, and describe the stratification of the world. Science is produced by the imaginative and disciplined work of humankind in examining what is given to them, but the instruments of the imagination are themselves provided by knowledge (Bhaskar, 2008). The way social science often works is that one does not predict results, one "postdicts" them. One analyses data, comes up with findings, and explains the findings after the fact. However, knowledge and understanding can come from imagination, reflection, and good ideas before or after data collection (Bernard, 2018:51), and the human actions and experiences from and by which knowledge is generated are thus always themselves social products (as is the knowledge generated). Therefore, "science as a process is always entirely intrinsic to 'thought'. However, by perception and experiment access to objects, viz. things, and causal structures, existing independently of thought may be obtained" (Bhaskar, 2008:176), and the way to arrive at knowledge is epistemology. Epistemology is about strategic choices, such as how to know something, or whether to conduct participant observation fieldwork, dig up information from libraries and archives, conduct a survey, or run an experiment. Strategic epistemological choices are choices of strategic methods, which means that they can comprise a set of methods and techniques from research design, fieldwork or experiments, analysis, and discussion of the results used to reach the study's conclusions (Bernard, 2018).

The epistemological orientations that inspired this study are interpretivism combined with critical realism (Bhaskar, 2008; Clark et al., 2021; Lawani, 2021). Interpretivism is an epistemology that "is based on the view that there are fundamental differences between people and the objects of the natural sciences" (Clark et al., 2021:25). Therefore, social science requires distinct research methods that consider the differences between the natural world and the social or human one (Clark et al., 2021). In the interpretivism methodological orientation, social science "methods require the researcher to grasp the subjective experience of social actions, what these experiences mean in practice, how those experiences and meanings are understood by others, and why they are interpreted in such ways" (Clark et al., 2021:25). Associated with interpretivism, this research relies on critical realism, which is based on the insight that "knowledge is obtained by observing and interpreting meaning to explain the elements of reality that must exist prior to the events and experiences that occurred" (Lawani, 2021:322). Critical realism acknowledges the reality of the order and phenomena of nature and the events, discourses, and actions of the social world, incorporating theoretical ideas and explanations that help explain local phenomena (Clark et al., 2021; Lawani, 2021). People may be able to understand and so change the social world if they identify the structures at work that generate those events, discourses, and actions, which can be identified, described, and explained through the practical and theoretical work of the social sciences (Bhaskar, 2008; Clark et al., 2021). The combination of interpretivism and critical realism generates complementarity in the research process, analysis, and interpretation regarding phenomena or events that occur in society. This is exactly what this study does, since the study assesses the flood risk, and analyses and interprets the results, clarifying how flood hazards and risks have been distributed in Matola and their effects on people and infrastructure. In addition, the study analyses, interprets, and explains the experiences and actions of social actors (e.g., urban planners and community members) and structures (e.g., the urban planning sector and the local community) in dealing with floods in Matola and in promoting resilience, as the centre of the research process, a scientific stance defended both by interpretivism and by critical realism.

In social science research methodology, we usually distinguish between qualitative and quantitative approaches (Bernard, 2018; Clark et al., 2021), whose propositions are accepted and explicit in some schools and not in others (Clark et al., 2021; De Vaus, 2001). In the qualitative approach, qualitative methods are used to explore the meanings of people's worlds – the myriad personal impacts of impersonal social structures, and the nature and causes of individual actors' behaviours (Brockington & Sullivan, 2003:57) – generating deep insights into particular topics, doing so through considered engagement with places and social actors. Qualitative methods explore actors and structures, which include people, communities, and organizations, as well as focusing on discourses, actions, and experiences (Clark et al., 2021). In any scientific research, it is important to consider the quality of the endeavour, particularly the quality of the product and the quality of the process of the research work. This might include the quality of the involvement of community members at each stage of the research – i.e., conception, development, data collection, and analysis – from which the product results (Laws et al., 2003; Bernard, 2018).

According to Clark et al. (2021), qualitative research is broadly interpretivist in nature, meaning that it tries to generate an understanding of the social world by examining how its participants interpret it. It has an ontological position that can be described as constructionist, in that social properties or characteristics are seen as outcomes of the interaction between individuals, rather than as phenomena that are "out there" and separate from those involved in constructing them. In turn, the quantitative approach is applied in the social sciences by turning words into numbers, classes, content, free lists, pile sorts, and graphs (Bernard, 2018). Quantitative methods in the social sciences serve to analyse problems of social reality, to describe and compare the characteristics of social groups, realities, contexts, or institutions, to establish causal relationships, or to check the effects of variables, their extent, and the block effect of one series of independent variables on another. Quantitative methods are also used to infer results for a population from the results obtained from a representative sample, and these results may be present in a single study or may be used in different or multiple studies (Clark et al., 2021; Mayoux, 2006).

According to Bernard (2018:355), in social science, qualitative analyses involve reducing people to words, to "wording about the meaning of their words, action, or artefacts", while most quantitative analyses in social science involve reducing people observed directly or through their texts to numbers. The qualitative approach may be used to search, describe, and present in meaningful words the results of quantitative analysis and processing (Bernard, 2018). Quantitative information can be obtained through participatory and qualitative methods, and qualitative information can be obtained as part of quantitative surveys or using participatory methods (Mayoux, 2006). These two approaches are combined in much research today, both quantitative and qualitative, involving data visualization, not just looking for patterns in the data, but describing and explaining them, showing the patterns as maps, networks, and matrices (Bernard, 2018). Although the quantitative research approach was initially developed for use in natural science studies, which adopted a positivist philosophy of knowledge that emphasized objectivity and the quantification of phenomena (Clark et al., 2021), this approach can indeed be used in social research and be combined with the qualitative approach to research and data analysis.

6.2. Research design

6.2.1. A case study research design

This study of flood risk and strategies, measures, and actions to promote resilience in Matola adopted a case study research design. A research design is a work plan that details what has to be done to complete the project that flows from the projected research design (De Vaus, 2001). A case study design specifies the unit of analysis about which information is collected. Individuals, units of a marriage, a family, places such as a block of housing, a community, a region or a country can all serve as cases, as can a school, a government department, a region, a period, or various other phenomena (Clark et al., 2021). A case study may be undertaken as background research to assess the need for and feasibility of a particular type of intervention; it may constitute part of an ongoing process of information gathering, or be part of a process of evaluation (McGregor, 2006:201).

A case study could involve understanding the decisions and actions about an issue or phenomenon taken by individuals (communities, technicians, politicians, or institutions) as a whole, examining the process by which the decisions were made, the participants in the process, the consequences, etc. (Clark et al., 2021; McGregor, 2006). The various of elements of case study designs allow for different ways to structure case studies, such as descriptive, exploratory, or explanatory, theory-testing or theory-building case studies (Clark et al., 2021; Yin, 2014). A case study can examine single or multiple cases or use a comparative design – studying two contrasting cases using more or less identical methods, which implies that social phenomena can be better understood when they are compared with one or more meaningfully contrasting cases or situations (Clark et al., 2021:62). A case study can examine holistic or embedded units of analysis, can be parallel or sequential, retrospective or prospective. Any technique of data collection can be used in a case study design as long as it is practical, ethical, and complies with research ethics requirements.

This study of flood vulnerability and the quest for resilience in Matola, Mozambique, is an explanatory case study. The explanatory case study design is relevant to this study because it requires an extensive description and explanation of some social phenomena (Clark et al., 2021; Yin, 2014). The more the study questions seek to explain some circumstances and social phenomena, the more case study research will be relevant (Yin, 2014). In this research, the case study goes beyond looking at the location and the flood phenomenon that occurred as a case. This study assesses the risk of flooding combining the retrospective and prospective perspectives. The study involves a retrospective analysis by assessing the vulnerability to and risk of flooding in the past, and a prospective perspective, assessing the vulnerability to and risk of floods in the future, whose analytical results can inform the development of plans for flood mitigation and adaptation measures and actions so that Matola can become more resilient to floods in the future. In addition, the study describes measures and strategies for promoting flood resilience and explains how have urban planners, and community members acted through resources at their disposal to contribute to promoting flood resilience in Matola. This research design structure is what is generally considered a complex type of case study (De Vaus, 2001; Yin, 2014). According to Yin (2014), case study research remains one of the most challenging of all social science endeavours when it comes to complex cases. The choice of the case study method resides in the fact of being relevant to this type of research in which the questions seek to explain a contemporary phenomenon, and it is also relevant because the questions require an extensive description of flooding and inquiry into flood resilience in Matola.

6.2.2. A mixed-methods case study

The overall aim of this thesis is to investigate the challenges of promoting resilience to urban floods in Matola, Mozambique. The research questions were designed to direct the study from different angles that required different combinations of methods, which is why the study used a mixed-methods approach.

Many successful studies use qualitative techniques in conjunction with quantitative ones, conducting interviews or focus group discussions to help the researcher understand survey results (Collins et al., 2007). The combination of different approaches, such as qualitative techniques in conjunction with quantitative ones when collecting empirical data on social facts and when analysing the generated data, enriches the research by allowing for scientifically desirable and complementary results, clarifying the case under study (Brockington & Sullivan, 2003; Collins et al., 2007).

This study accordingly combines quantitative and qualitative approaches to collecting and processing flood research data, empirical data from interviews with urban planners and community members in areas at risk of flooding, and data from observations, triangulating these with secondary data. The use of qualitative techniques in conjunction with quantitative ones was indispensable when collecting the empirical data. Through direct contact, social facts were observed and analysed within the context to which they belong, with the researcher playing a fundamental role in the observation, selection, consolidation, and analysis of the generated data. The intersection of these approaches ensures the complementarity required for this study, with its intense and in-depth data collection, data processing, and analysis of the object of study.

A quantitative flood risk assessment based on hydrological or/and hydraulic models was first conducted (Paper I). The flood risk assessment consisted of using GIS software and GIS modelling tools; geographical data, for example, on the local topography, precipitation, and population were introduced, processed, and analysed using the TFM-DYN model to produce results expressed in graphical tables and flood hazard and risk maps. This approach was necessary to determine areas of different flood risk levels in Matola; the information obtained supported interviews with urban planners (Paper II) and interviews and focus group discussions with community members (Paper III). The results of the flood risk assessment also made it possible to select areas where members of communities that experienced flooding would be found, with whom semi-structured interviews and focus group discussions were carried out. In general, the interviews focused on mitigation and adaptation measures, and actions to promote resilience to floods in Matola.

Second, the design involves using techniques such as semi-structured interviews and focus group discussions as components of the investigation. With this design, interview guides containing open-ended and closed questions were formulated and used for the semi-structured interviews and focus group discussions. The answers to the open-ended questions were analysed qualitatively, while the answers to the closed ones were quantitatively analysed and the results usually presented in numbers or percentages. This allowed us to measure and group the answers and to describe the opinions of the sample representing the target group of the research. The analysis also included images captured on the ground resulting from observation, which served to support and reinforce the data from the interviews. Based on the qualitative and quantitative methodological approaches regarding the research questions, the data-collecting methods and tools used in the field research are described below.

6.3. The study area

The study area corresponds to Matola located beside Maputo Bay in southern Mozambique, between the parallels 25º41’ and 26º00’ south and the meridians 32º24’ and 32º55’ east (see Figure 6.1). With an estimated area of 368.4 km², it is entirety a plain with elevations ranging from 0 to 66 meters above sea level. The areas from 0 to 27 meters above sea level are highly flood prone, representing the flood basin of the Matola and Infulune rivers, often flooded by rainwater runoff from the highest areas of the Municipality of Matola.

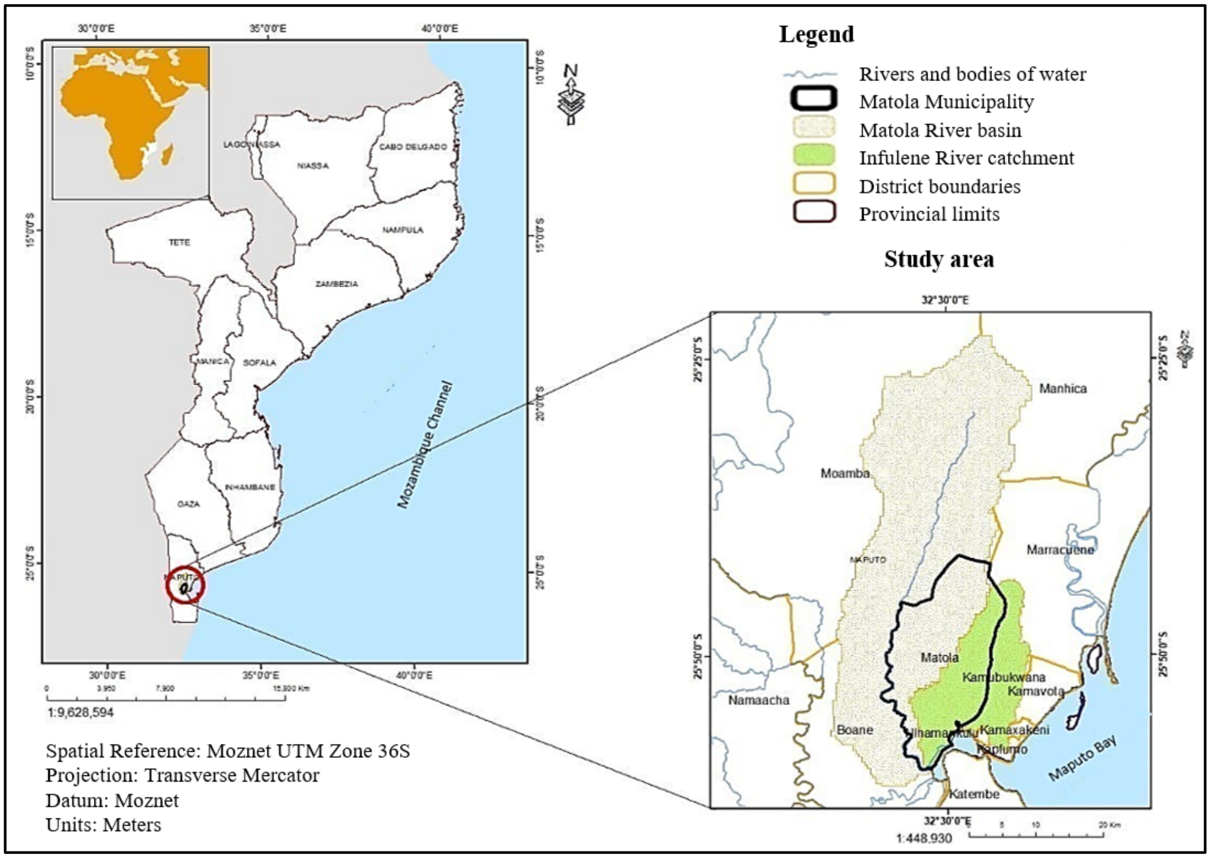

Figure 6.1: Location of Matola (source: author).

Matola is divided into three administrative areas, namely: Posto Administrativo da Matola Sede with 13 neighbourhoods, Posto Administrativo da Machava also with 13 neighbourhoods, and Posto Administrativo da Infulene with 15 neighbourhoods, for a total of 41 neighbourhoods (CMCM, 2010). At the time of the 2000 floods, Matola had an estimated population of 424,662 inhabitants (INE, 1998) and a population density of 1153 inhabitants/km2. Of the total area, 20.21% was occupied by housing, commercial, industrial, and social infrastructure, 21.51% by agriculture, 2.06% by bodies of water, 1.14% by wetlands and swamps, and the remaining 55.08% by natural vegetation including grassland, herbs, shrubs, and trees.

Industry is the basis of the economy of Matola, which has the largest industrial park in Mozambique, concentrating around 60% of the national industry. The over 500 industrial units that make up this park have a high degree of diversification, ranging from agro-industrial to metalworking and construction materials, and are associated with the port of Matola. There is also salt mining next to Maputo Bay (GPM, 2016).

Strongly linked to industrial growth, the old urbanized area emerged as a dormitory city of formal settlements, i.e., well-ordered areas with conventional infrastructure and public services such as hospitals and schools. This industrial growth was accompanied by spreading informal settlements, i.e., disorganized areas of occupation without conventional infrastructure or public services. There is also an irrigated agricultural area along the lower Infulene River, and other rainfed agriculture to the north of the Municipality. The urbanization has increased, and Matola has an estimated population of 1,915,000 inhabitants as of 2024 (UN-World Population Prospects, 2024), mixing new urbanized neighbourhoods with the old formal and informal settlements. Currently, with accelerated urbanization, Matola has typical urban public and private services, such as financial institutions, commercial facilities, hotels, leisure and recreation amenities, education, and health services spread across the city.

6.4. Data collection techniques

6.4.1. Bibliographic research

In this study, the literature review and theoretical framework were based on selected and relevant scientific-academic studies, so a strategy and inclusion criteria identifying relevant articles and books were used. The strategy consisted of using the search terms in databases containing books and articles related to the terms. The databases used were Google Scholar, Web of Science Core Collection, the University of Gothenburg Online Library, and Google Alerts. Published physical books were also selected.

The inclusion criteria of the different categories of studies searched were as follows: types of studies (empirical, conceptual, and theoretical studies); focus (understanding DRR, flood vulnerability and risk; resilience; flood resilience, urban planning and management for flood resilience; community resilience to flooding; actor, structure, and agency theory); publication type (journal articles, books, book chapters, reports, working papers, conference proceedings, and encyclopaedia articles); language (English and Portuguese); and time period, particularly for literature review (publication year: 2000–2024). Anything else that did not meet the inclusion criteria was excluded, and all sources are properly cited and listed in the bibliographical references of the papers and thesis. These sources served to build, on one hand, the conceptual and theoretical basis on which the concepts supporting the research were presented and discussed and, on the other hand, a methodological basis that allowed for the formulation of the project and fieldwork, and for writing, discussing, and presenting the final work.

Documentary research was also conducted using inventories of reports, urban plans of Matola, strategic plans, regulations, and legislation related to municipal and urban territorial management. These sources were obtained from the online platforms or websites of different Mozambican government institutions and international institutions. Other sources were obtained physically and electronically from government institutions. The criterion used for inclusion was the relevance of the content to this research. These sources provided relevant and useful information for the thesis, such as: regulations on the legal framework for urban planning in Matola, information on actions taken in relation to floods, and important statistical information that provided demographic and socio-economic background on Matola.

6.4.2. Data collection for GIS flood hazard and flood risk analysis

In this study, data were collected for GIS flood hazard and flood risk analysis for Matola flood risk assessment based on a hydrological model. To determine the location of the study area on a geographic location map using ArcGIS software, data were collected from the existing geographic database of the National Center for Cartography and Remote Sensing of Mozambique (CENACARTA). For analysis using ArcGIS software, the input data, which include a digital elevation model and land use/land cover (LULC) data for the Matola and Infulene catchments for the year 2000, were collected from the US Geological Survey (USGS). Daily precipitation data were collected from eight measurement stations in the Matola and Infulene catchments for the year 2000 from the South Regional Water Administration (ARA-SUL) of the National Directorate of Water Resources Management (DNGRH) of Mozambique. Surface roughness coefficients and infiltration values assigned to each LULC were produced using ArcGIS software. The surface roughness coefficients and infiltration values assigned to each LULC class are necessary as input data along with other data on precipitation, population, etc., in ArcGIS software for flood risk assessment. Finally, Matola population data for 2000, 2020, and 2040 were collected from the National Institute of Statistics (INE) of Mozambique.

6.4.3. Semi-structured interviews

The semi-structured interview was one of the techniques used, being particularly relevant to collecting data on the flood experiences of Matola's urban planners and community members, and on the actions, measures, and strategies used by these actors in promoting flood resilience. A semi-structured interview consists of an open conversation about a particular subject (Brockington & Sullivan, 2003), following an interview schedule or guide containing suggested themes addressed by semi-structured questions (Bernard, 2018; Clark et al., 2021). The interviewer does not have to ask the questions exactly as outlined in the guide, and in some circumstances, the interviewer can ask questions that were not planned in order to follow up on interviewees' replies (Clark et al., 2021). In a semi-structured interview, there is scope for the interviewees to develop their responses; they can respond freely, and during the conversation can even address questions that have not yet been asked. It is up to the interviewer to control the answers or the conversation according to the guide, and to ensure that all questions are answered (Bernard, 2018; Clark et al., 2021; Laws et al., 2003).

In this research, the semi-structured interviews were conducted using open-ended questions and some closed ones as contained in an interview guide (see Collins et al., 2007). Open-ended questions gathered rich qualitative data from each respondent's candid responses in open conversations with urban planners and community members. Closed-ended questions were used to capture urban planners' perceptions of Matola's preparedness to face future floods, given the risk of flooding it is exposed to.

Based on semi-structured interviews, information was obtained from 32 technicians from the urban planning sector, and from respondents from the construction/infrastructure and municipal finance sectors. This information was about these respondents' knowledge, experience, and awareness of the direct impacts of floods on the Municipality of Matola and of the forms of mitigation or adaptation used or integrated in the urban planning process since the 2000 floods, to build and promote urban flood resilience. It was important to know about whether the community members were involved in addressing urban planning issues, particularly as related to floods, and in decision-making, mitigation actions, and flood adaptation, as well as how they benefited from the outcomes of the measures taken. It was also important to know urban planners' opinions about future prospects, considering that most of the urban area of Matola faces different levels of flood risk.

The semi-structured interview was also the method used for the conversations with 18 community members of Matola, supported by direct observation. The study sought responses about the measures taken so far and about the future in terms of the forms of adaptation or mitigation that residents could use in case of repeated or permanent flooding. Based on the interviews, it was possible to get information about how community members acted in their communities to promote resilience to flooding, and how they were involved in flood mitigation and adaptation measures and actions developed by the Municipality of Matola, with a view to making their habitations safe from possible floods in the future.

6.4.4. Focus group discussions

Focus group discussions, also referred to as "group depth discussions", are group-based interviews typically lasting one and a half to three hours and involving around six to eight (Lloyd-Evans, 2006:153) or six to ten participants (Clark et al., 2021:457). A focus group is a group discussion on a particular issue in which it is instructive to observe how people discuss things as much as what they say (Brockington & Sullivan, 2003:58). Focus groups can be used as a stand-alone technique, but they are mostly employed as part of a multi-method approach to field research in social research (Brockington & Sullivan, 2003; Clark et al., 2021; Lloyd-Evans, 2006). The moderator uses a small number of very general questions to guide the focus group session, giving the participants considerable freedom, allowing the discussion to range as widely as is necessary, but can carefully refocus the participants' attention, if necessary (Clark et al., 2021).

Individual human behaviour is influenced by collective behaviour and thought, so the focus group discussion can be as important as the in-depth interview in understanding the importance of codes of behaviour and "ways of doing" in relation to a wide range of political, social, and economic activities (Lloyd-Evans, 2006:154). Focus group discussions allow researchers to study the process through which individuals collectively make sense of a phenomenon and construct meanings around it. The discussions reflect how meanings are constructed in everyday life, meaning that this method can be seen as more naturalistic than individual interviews (Clark et al., 2021:454).

In this study, three focus group discussions were conducted, corresponding to the three administrative areas. They included 24 participants living in risk areas and who had experienced the 2000 flood. This method made it possible to seek a sense of community among Matola residents and to obtain more general and common opinions about how communities acted collectively in facing the floods.

6.4.5. Direct observation

Direct observation is a method of collecting data through direct contact with the phenomena or individuals under study and taking notes. Observation seeks to capture and understand phenomena, social, cultural and psychological characteristics considering the context in which behaviour and events occur (Bernard, 2018; Clark et al., 2021). Through direct observation, various situations in the study area could be observed on the ground. These situations included the form of current land occupation (e.g., areas of socio-economic infrastructure), the location of green areas, and the coastal protection areas and floodable areas of the Matola and Infulene rivers. Observation was done on the ground of the mitigation or adaptation measures carried out in practice through observation notes. Photographic images were taken as a basis for analysis and testimony regarding the flood mitigation and adaptation measures and actions being taken by the urban planning sector of the Municipality of Matola to promote flood resilience. The use of direct observation allowed the collection of images of the settlements and habitation conditions of the population residing in flood-risk areas. These include images of actions, such as construction, taken to reduce, mitigate, and adapt to floods. In addition to oral testimony, the images are illustrative of the socio-spatial reality of the Matola and Infulene floodplains in the Municipality of Matola.

6.5. Selection of study population

6.5.1. Selection strategies

In selecting the study population and in sampling, this study is based on non-probability sampling, especially purposive sampling used in choosing informants (Bernard, 2002). This strategy of choosing informants was used to find people who had specific characteristics and knowledge of the subject studied here. The first purposive sampling targeted technicians from Matola’s urban planning sector, because they have knowledge, experience, and judgment as experts on flooding in Matola neighbourhoods. These technicians or urban planners may have knowledge of how to determine vulnerable and flood-risk areas and of actions carried out in practice, both in urban planning and for implementing adaptation and mitigation strategies set forth in urban plans to make Matola resilient to floods. The second purposive sampling targeted community members for interviews and focus group discussions, people who had experienced the floods of 2000 and who lived in or around areas subject to flooding in Matola.

6.5.2. Informants: urban planners

The technical informants from the Municipality of Matola were urban planners. Within the municipal administration as an urban management institution, different sectors interact for the same purpose, which is Matola's urban development. Based on this assumption, not only planning technicians were selected as the study population but also technicians from other sub-sectors that participate or cooperate in urban planning. Thus, 30 technicians assigned to the Council of Territorial Planning and Urbanization, one from the Council of Construction and Infrastructure, and one from Municipal Finances constituted the sample of urban planners of Matola selected for semi-structured interviews.

6.5.3. Informants: community members

The analysis of Matola's flood risk shows that, although most of the area has very low flood risk and low risk prevails, medium and high flood-risk areas are spread across the three administrative areas of the municipality, hence the challenge of deciding who to select as the sample of community informants. The informants finally consisted of 42 members of the communities of Matola. The selection of informants took into consideration three criteria: (i) spatial location in Matola, (ii) sex, and (iii) and age. These criteria were used for both the interviews and focus group discussions, as explained below.

For the location criterion, the informants were selected from among residents who lived in or around areas subject to flooding and in places where the risk of floods was low in the Matola and Infulene river watersheds and in coastal protection areas. The population residing in the flood-risk areas of Matola was chosen because these areas suffered the most during the 2000 floods so people there know more about the incident. Associated with this, this population is still in a place of risk, i.e., areas vulnerable to flooding, so it is important and relevant to hear from them about what adaptation and mitigation and measures are used to promote resilience to flooding. Still using the criterion of the area of flood risk occurrence, some neighbourhoods with the largest areas at high risk of flooding were selected in the three administrative areas of Matola, from which were selected informants for focus group discussion. In turn, the interviewees were selected from other neighbourhoods spread across Matola, which are also at risk of flooding. Thus, from these informants, it would be possible to obtain relevant and detailed information about the devastation that the 2000 floods caused, the damage caused by later floods of lesser magnitude, and the actions and measures to promote resilience. Furthermore, in these areas, flood scenarios and some practical actions to promote resilience could be observed and captured by photography during fieldwork.

The sample of 42 individuals was divided into two groups, one for semi-structured interviews and the other for focus group discussions. Individual semi-structured interviews were carried out with 18 informants spread across the three administrative areas: seven from Machava Sede, six from Matola Sede, and five from Infulene. The second method used was the three focus group discussions, including 24 participants living in or around areas vulnerable to flooding and that experienced the 2000 flood, corresponding to three administrative posts: Machava Sede, nine participants; Matola Sede, eight participants; and Infulene, seven participants. The use of semi-structured interviews with informants from across the three administrative areas would allow the researcher to obtain answers with a more individual focus, although they would answer the same questions posed during the focus group discussions. In turn, with focus group discussions it would be possible to seek a sense of community among Matola residents and to obtain more general and shared opinions, and learn about how community members acted when dealing with floods.

Regarding the sex criterion, half of the interviewed informants were of each sex, because studies of flood vulnerability reveal that vulnerability differs between the sexes. Studies of vulnerability to natural disasters show that women are generally described as more vulnerable to natural hazards than men because of their gendered responsibilities in family life, sector-specific jobs, and lower earnings (Müller et al., 2011). That is why it was relevant to ensure that we learned about the experiences and actions of as many women as men in relation to the 2000 floods and the more recent floods in Matola.

Regarding the age criterion, the selected informants were aged 30 years and above because they would be people with memories of what happened in 2000, who could tell about what they experienced when these floods occurred. Moreover, these people could also report about their experiences from 2000 to the present, in terms of reasons why they remained living in these places even after this flood, and after later floods in 2014–2015 and 2019, which again showed that these places are inappropriate for habitation.

6.6. The fieldwork process

The fieldwork was carried out in three phases: the first was the pre-visit carried out between June and August 2018, the second from November 2020 to January 2021, and the third from June to July 2022.

6.6.1. Pre-visit

The pre-visit phase in Matola was carried out between June and August 2018, within the scope of designing the research project. The purpose of the visit was to observe the local situation in terms of land use and occupation, to observe possible signs of destruction caused by floods in the city, to observe possible signs of change in the landscape resulting from the floods of 2000, and to visit possible flooded places. In addition, the aim was to talk informally with some residents and municipal urban planning technicians, with a view to collecting information for elaborating the research project. From the observations made, it was possible to conclude that this was an area that needed research, as the conversations made it possible to ascertain the concern that residents had about the real risk of flooding that Matola faces, as well as the challenges that urban planners and community members faced in developing adaptation and mitigation measures.

6.6.2. Fieldwork in 2020–2021

The first data collection fieldwork with official permission for the purpose was conducted from November 2020 to January 2021. Data were mainly collected through semi-structured interviews with 32 urban planners in Matola. These planners were accessed through a formal request to the President of the Municipal Council of the City of Matola, who formally authorized and instructed the directorates to make the planners available for interviews according to a calendar. Of the 32 urban planners, 30 were assigned to the Council of Territorial Planning and Urbanization, one to the Council of Construction and Infrastructure, and one to Municipal Finances. The study maintained the anonymity of the study participants. Semi-structured interviews were conducted using an interview guide (Appendix 1), which served to direct the conversation. Semi-structured interviews were also conducted with some community members, using an interview guide with open-ended questions, (Appendix 2). In addition to the interviews, direct observations were conducted in Matola's neighbourhoods and photographic images were taken.

6.6.3. Fieldwork in 2022

Fieldwork in this phase was carried out in June and July 2022. During this period, semi-structured interviews and focus group discussions were conducted in the three administrative areas Machava Sede, Matola Sede, and Infulene. Using an interview guide (Appendix 2), this time the conversations were with community members living in or around areas vulnerable to flooding and who had experienced the 2000 flood. To complement the research, direct observations were made throughout this research period, including capturing photographic images that can testify to the facts described and analysed in the study, showing some measures or actions taken to promote resilience to flooding in Matola.

6.7. Data analyses

This study submitted biophysical and socio-economic data to a set of quantitative and qualitative analysis techniques. Analysis is the search for patterns in data and for ideas that help explain why those patterns are there in the first place (Bernard, 2018:355). The analysis of the results was supported by methodological triangulation (Heesen et al., 2016; Valencia, 2022), as the use of mixed quantitative and qualitative methods was necessary to answer the study's research questions. This analysis involved triangulating differentiated data resulting from geoprocessing in ArcGIS in assessing flood risk in Matola, and triangulating interviews, focus group discussions, and observation data. The analytical tools used are presented below.

6.7.1. Land use/land cover (LULC) analysis and surface water modelling

Urban pluvial flood modelling based on GIS analysis produced flood hazard maps and risk maps of Matola for 2000, 2020, and 2040. To achieve this, it was first necessary to produce maps of the evolution of land use/land cover (LULC) in Matola for 2000, 2020, and 2040. Here the evolutionary analysis of LULC and the hydrological analysis were carried out within the area corresponding to two hydrographic basins, considering that Matola is located in the hydrographic basins of the Matola and Infulene rivers. In this way, data processing and the analysis of flood hazard and flood were developed taking into account these two river basins, to extract the results for Matola (see Figure 6.2).

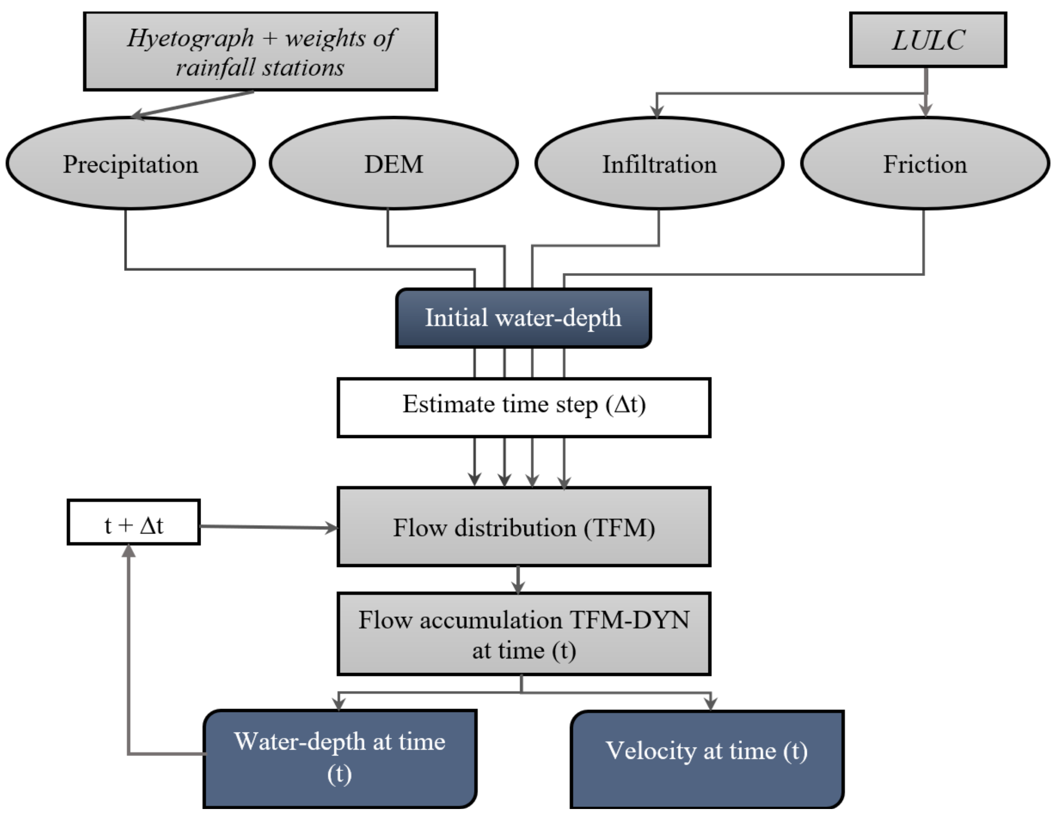

Figure 6.2: The TFM-DYN conceptual model used for flood risk assessment in Matola (source: Pilesjö & Hasan, 2014).

LULC data covering the study area were extracted using 30-m-resolution satellite images from 2000 and 2020 downloaded from the USGS website, while for the year 2040, urbanization was simulated in ArcGIS 10.5.1 to create an estimation of LULC. The LULC classes used were based on classes from the National Cartography and Remote Sensing Centre in Mozambique

(CENACARTA). For surface water modelling, this study used a later developed version of the triangular form-based multiple flow (TFM) algorithm model developed by Pilesjö and Hasan (2014). The model is dynamic and denoted TFM-DYN, and it requires few and readily available input data (see Figure 6.2).

The model simulates flow and produces estimations of water depth and velocity in an area over time, allowing for the analysis of water depth and velocity over temporal and spatial windows. Elevation, precipitation, surface roughness, and infiltration in the form of ASCII raster data are required to run the model. In this case, ArcMap version 10.5.1 (with Spatial Analyst) and Python version 3.4 software were used to process the input data, analyse the results, and visualize the resulting maps (see Paper I).

6.7.2. Descriptive statistics: quantitative data analysis

Descriptive statistics were used in analysing quantitative data resulting from ArcGIS 10.5.1 processing of the flood hazard and risk in Matola, as well as the data resulting from the answers to the closed questions asked of the interviewees. Descriptive statistics were applied in describing the percentage of the Matola study area covered by each LULC class in 2000, 2020, and 2040, resulting from the GIS processing and analysis, particularly in the ArcGIS 10.5.1 simulations. They were also useful in describing the results of the analysis of daily precipitation data from eight measurement stations in the Matola and Infulene catchments in 2000, and were applied in describing and analysing the results processed in the TFM-DYN model of the distribution of hazard (i.e., water depth and velocity) and flood risk in Matola (see Paper I). Using the SPSS platform, descriptive statistics were used to explore urban planners'/technicians' perceptions of Matola's preparedness for future floods (see Paper II). This analysis was done in combination with the results of the qualitative data analysis presented in the next subsection.

6.7.3. Explanatory analysis: qualitative data analysis

The process of analysing qualitative data consisted of transcribing, analysing, and explaining the empirical data obtained in the field. NVivo software was useful in this phase of the research to organize and analyse the contents of interviews and focus group discussions. The analysis began with identifying the most important concepts on which the research is based, such as: first, flood vulnerability and risk in terms of urban planners' and community members' knowledge and experience of floods and their causes in Matola; and, second, flood resilience, focusing on mitigation and adaptation measures developed and implemented so far by the community and the urban planning sector in Matola.

Specifically, in Paper II, the analysis explores the actions the urban planners took during the 2000 major flood event, the flood adaptation and mitigation strategies and measures for increased flood resilience they developed after that event, and the contribution of urban planning to building flood resilience in Matola. In Paper III, the analysis explores actions or measures the communities in Matola have developed to cope with urban flooding since 2000, in light of the dimensions of community resilience, by building or promoting flood resilience in Matola.

The methodological crossover allowed for methodological and data triangulation, providing insightful conclusions about how urban planners and community members in Matola approach flood adaptation and mitigation measures and actions, and strategies for flood resilience, in a context of financial, technical, and livelihood constraints (Papers II and III).

6.8. Ethical considerations in research

In addition to achieving academic and professional growth, this study was conducted to contribute new and innovative knowledge of flood risk assessment and flood resilience approaches in a context of financial, technical, and livelihood constraints. The thesis project was conceived to address the research questions while considering the ethical issues involved (Vetenskapsrådet, 2017). According to Scheyvens et al. (2003), the research process must ensure the participants' respect, privacy, dignity, and safety. Among several issues that can be highlighted in the context of developing research, three central issues received great attention in this study, namely: informed consent, privacy, and conflict of interest. Informed consent is when an informant or participant, with a full understanding of the research, freely agrees to take part in the study. This means that informants or participants are aware of what the research is about, its objectives, and the likely implications of taking part in the research (Scheyvens et al., 2003; Vetenskapsrådet, 2017). Privacy includes the idea of confidentiality, and anonymity "refers to the researcher's responsibility to keep the identity of participants private, if they so wish, so that they will not be personally identifiable in any outputs … produced by the researcher" (Scheyvens et al., 2003:146). To preserve privacy, confidentiality, and anonymity, the way in which research results are presented should not reveal the identity and characteristics of research participants, to the point of their being personally identified. In turn, conflict of interest is when trust and loyalty among research participants, such as researchers, supervisors, the university, and funders, are placed at risk for any reason. This may result in the separation of parties, the withdrawal or abandonment of one or several parties, the replacement of research partners or supervisors, and, in serious cases, the withdrawal of all parties or cancellation of the research (Scheyvens et al., 2003; Vetenskapsrådet, 2017).

Several individuals participated in the research as supervisors, collaborators, and informants. The relationships among the study's author, supervisors, and collaborators were always good, and any issues arising while conducting the study were resolved by consensus and without any conflicts of interest.

Regarding the informants questioned about the object of study and therefore deserving respect, their dignity and social integrity were safeguarded in their professional and community environments. Semi-structured interviews were conducted with urban planners of Matola, and semi-structured interviews and focus group discussions were conducted with community members living in and around areas vulnerable to flooding. The interviews addressed urban planning activities that could ultimately touch on sensitive urban-land-use issues related to the interests of other social and political actors. The interviews and focus group discussions addressed several sensitive community issues concerning access to and use of land, which could be legal or illegal. This study was therefore carried out seeking to uphold the assumptions of informed consent, confidentiality, and avoiding conflict of interest.

Therefore, it was important to first obtain official permission from local municipal authorities to conduct interviews and focus group discussions, with both urban planners and community members. We then contacted and talked with the leaders of the sectors where urban planners are located, as well as with urban planners, community leaders, and community members from the various neighbourhoods selected for interviews and focus group discussions. The conversations sought to make leaders, urban planners, and community members understand that the research was intended to enable my academic and professional growth. It was also essential to make them understand that the research was not of a partisan political nature, nor was it intended to compromise their professional careers or leadership and network relationships with community members. It was essential to clarify to the informants that the research would safeguard privacy, with the study results keeping the informants anonymous, so that the interviewees could not be personally identified by the readers, preventing any type of conflict between the participants. Furthermore, it was important to explain to the informants that the study could reveal what worked well or poorly in promoting flood resilience in Matola, and could inspire the improvement of actions, measures, and strategies to promote flood resilience. After clarifying these matters to the informants, all those invited chose to participate in the interviews and focus group discussions freely, and conscious of the research.

6.9. Limitations and challenges of the research

The research had two main limitations and challenges. The first was related to the difficulty of accessing updated data necessary for the hydrological modelling, to assess flood vulnerability and risk. Due to the lack of access to population data updated by neighbourhood for the years 2000, 2020, and 2040, the study used population data from the latest applicable censuses. For the year 2000, data from the 1997 census was used. In addition to data on the total population divided by sex, the study had access to data on the distribution of the population across the 41 neighbourhoods of Matola. For the year 2020, the study only had access to data on the total population of Matola from the 2017 general population census. For 2040, the study only accessed data on the total population of Matola from the demographic projections of Mozambique. The use of these data was a challenge for the study, in determining the risk of flooding in the years 2000, 2020, and 2040, since the population must be spatially distributed along with other data, such as the spatial distribution of the hazards of water velocity and depth, together with LULC, at the time of processing this data in the GIS to generate flood risk maps. However, this does not mean a lack of reliability, validity, and credibility, as it is necessary to understand that the study was developed precisely to demonstrate that, even given scarce data, it is possible to assess the hazard and risk of flooding, maps of which constitute an indispensable tool in territorial and urban planning.

The second challenge was about the selection of informants, i.e., the community members. The challenge was associated with the data collection techniques, i.e., semi-structured interviews and focus group discussions, as the study in this stage conducted qualitative research for qualitative analyses. With these techniques, it was not possible to include many informants, considering the large size of the population of Matola affected by the floods. However, it was possible to choose informants who could provide detailed and in-depth information about the object of study, according to the criteria presented in section 6.5 about sampling applied in the social sciences.

7. PAPER SUMMARIES

Paper I.

Neves, J.L.; Sellick, T.K.; Hasan, A. & Pilesjö, P. (2022). "Flood risk assessment under population growth and urban land use change in Matola, Mozambique". *African Geographical Review,* 42(5): 539–559. https://doi.org/10.1080/19376812.2022.2076133

This paper assesses the vulnerability to and risk of flooding considering present and future scenarios for Matola. The study aims to produce flood-hazard and flood-risk maps of Matola using the TFM-DYN hydrological model of Matola for 2000, 2020, and 2040. The specific objectives are to produce land use/land cover (LULC) evolution maps, flood-hazard maps, and risk maps of Matola for 2000, 2020, and 2040. Two research questions were addressed: 1) How are flood hazard and risk distributed in Matola in the past, present, and future, considering the various changes in land use, population, and climate-change scenarios? 2) How can flood-risk maps be developed given data scarcity?

The findings indicate that much of the total flooded area, i.e., 52.6% and 46.2%, was in the low-hazard class (0.01–0.5 m of depth) in 2000 and 2020, respectively. In 2040, the largest flooded area, i.e., 47.0% of Matola, is expected to be in the very-low-hazard flooding class (0–0.1 m of depth). Additionally, a significant flooded area is in the medium-hazard (0.5–1 m of depth), high-hazard (1–2 m of depth), and very-high-hazard (2–5 m of depth) flooding classes, increasing from 2000 to 2020 and 2040. It is clear that much of the area subject to high- and very-high-hazard flooding lies in or near the river channels. The water velocity findings indicate that in 2000, cells with a maximum velocity of 0.5–1 m/s occupied 33.0% of the area. In 2020, the scenario changed, and cells with a maximum velocity of 1–1.5 m/s occupied 27.5% of the area. The change is continuing, and by 2040 cells with a maximum velocity of 1–1.5 m/s will occupy 35.9% of the area of Matola. Cells with other maximum velocities are also undergoing changes resulting from LULC changes over the years, shifting the trajectory of water through buildings and other structures and changing the patterns of water accumulation.

The results indicate that, overall, most of the Matola area faces very low flooding risk, and areas facing the lowest-depth (0–0.01 m) flooding risk accounted for 49.4% of the area in 2000, 57.7% in 2020, and will account for 62.4% in 2040, affecting about half the population in each year. These are areas of very low or almost non-existent flood vulnerability, as their population and infrastructure are not exposed to the direct impact of flood disturbance. In turn, the medium- and high-flood-risk areas put many inhabitants in a vulnerable situation, although fewer than those in the very-low- and low-risk areas. In 2000, 61,978 inhabitants were exposed to medium risk of flooding in an area of 50.6 km2 and 53,037 inhabitants were exposed to high risk in an area of 43.3 km2. In 2020, 130,628 inhabitants were vulnerable to medium risk of flooding in an area of 44.8 km2 and 92,723 inhabitants were vulnerable to high risk in an area of 31.8 km2. In turn, in 2040, 203,100 inhabitants may face a medium risk of flooding in an area of 39.0 km2, corresponding to 10.6% of the area, and 151,169 inhabitants may face a high risk in an area of 28.9 km2. These findings show an increase in the extent of low-risk areas of flooding, and a decrease in the extent of medium/high-risk areas from 2000, through 2020, to 2040. However, the findings reveal an increase in the number of inhabitants exposed to combined medium/high-risk areas of medium/high-hazard classes of flooding ranging from 0.5 m to approximately 5 m in depth, due to the increase in markedly horizontal land occupation by socio-economic infrastructure. This horizontal urban spread is caused by commercial, housing, transport, and other infrastructures replacing agricultural, green, and floodplain areas with non-existent or deficient drainage systems, or other water-control systems needed for flood control, in both newly planned and informal, unplanned land development as found by Araújo (2003), Neves (2018) and Un-Habitat (2007). Changes in LULC and population growth play major roles in the changing risk profile over the years studied and in the consequent population increase in flood-vulnerable areas. The findings indicate the need for planned adaptation measures to cope with future urban flooding given the 2040 scenario presented in Matola.

Studies assessing the risk of flooding and including projections of future scenarios are essential for any part of the world, as pointed out by Alfieri et al. (2014), EU (2018), and Xu et al. (2021). Projections of future flood risk scenarios is especially and eminently needed in developing countries with accelerated growth in urban areas in recent decades, without being accompanied by water control and drainage systems that would help minimize the negative impacts of floods, as found by Douglas (2018) and Muis et al. (2015).

The study informs the academic community, flood risk managers, urban planners, and others interested in flood risk management by presenting a methodology that can be replicated for flood risk assessment considering present and future scenarios. This study helps fill a gap in research on specific urban area scenarios of future hazard and flood risk that include projected spatio-temporal transformations of land use generated by socio-economic development, which, according to Hinkel et al. (2014) and Muis et al. (2015), have received little attention in the flood-risk-projection academic community. By assessing the risk of flooding and including projections of future scenarios, the resulting maps are important for designing and implementing sustainable land-use plans, preventing flood losses, and advancing the development of flood mitigation and adaptation measures to promote flood resilience.

Paper II (manuscript)

Neves, J.L.: Urban planning for flood resilience: Challenges in building a resilient city under technical and financial constraints in Matola, Mozambique.
Current status: Submitted to *City and Environmental Interactions,* under review.

This paper studies the challenges of urban planning for urban flood resilience in Matola, Mozambique. Occurrences of floods as natural disasters are increasing globally. The African continent has suffered severe flooding in different locations during the past and at the beginning of this century. Southern Africa has suffered from intense cyclones associated with strong winds and heavy rains causing flooding in rural and urban areas. Matola, a major Mozambican city, located on a coastal plain in the catchments of the Matola and Infulene rivers, has witnessed many floods, mainly caused by rainfall. The most devastating one happened in the year 2000. This study aims to analyse the actions urban planners adopted during the major flood event, what flood adaptation and/or mitigation strategies for increased flood resilience they have developed since that flood event, and the contribution of urban planning to building flood resilience under financial and technical constraints and amid socio-political complexities. The study is based on interviews with 32 urban planners from Matola Municipality and field observations in the study area.

The findings show that rescuing, accommodating, and assisting flood victims during the 2000 floods were the mitigation actions immediately taken in Matola. The main strategy of the municipal administration to promote flood resilience in Matola after the 2000 floods, was capacity development training and employing staff of different specializations, essential for planning and managing land use and adaption measures, and implement measures gradually, such as designing a new urban plan, gradual resettlement, and gradual construction of drainage channels to promote flood resilience. Thus, urban resilience to floods was strategically addressed, doing what was feasible under the existing technical and financial conditions over time, to improve knowledge, mitigation, adjustments, and adaptation. These findings reveal that the approach to mitigation and adaptation measures to floods was to combine measures framed mainly in terms of socio-ecological resilience, such as emergency evacuation and accommodating people and goods in emergency centres and temporary shelters during disaster according to the assumptions of socio-ecological resilience, as found by Bertilsson et al. (2018) and Vitale et al. (2020).

The findings also reveal that several challenges undermine the promotion of flood resilience in Matola, such as population growth and rapid urban growth that exceeds the municipal capacity to keep pace with this growth by building new drainages and maintaining existing ones due to financial, material, and inspection personnel constraints, as found by Araujo (2003), Andreatta & Magalhães (2011) and Broto et al. (2015). The findings also show that the main challenge in promoting flood resilience in Matola is the insufficient coordinated mitigation and adaptation actions among urban planners and political elites. While urban planners take the adaptation agenda seriously, political interests concerning, e.g., land tenure issues, undermine urban development adjusted to adaptation and/or mitigation actions, as found by Andreatta & Magalhães (2011) and Artur & Hilhorst (2012), in some Mozambican cities. In the case of Matola, while urban planners plan to remove infrastructures from floodable areas, there are cases in which places vulnerable to flooding are occupied by housing and commercial infrastructure by citizens with land use right licenses (DUATs) granted by the Municipality of Matola through the influence of political leaders. In turn, members of some low-income urban communities use the floodplain for housing and other socio-economic infrastructures, purposes that contradict resilience-building actions.

The study concludes that, despite the above challenges, urban planning contributed significantly to the building and promotion of flood resilience in Matola because the strategies and measures taken so far have contributed significantly to reducing exposure and vulnerability to the flooding of the population, assets, and urban infrastructure. Furthermore, urban planning favoured the improvement of the ecosystem in the lowlands and coastal protection wetlands, as the removal of infrastructure in some of these areas allows them to carry out their function of draining water and developing the fauna and vegetation typical of these habitats in line with Aldunce et al. (2015), Sayers et al. (2013) and Vitale et al. (2020).

The study shows that socio-ecological resilience can be strategically addressed using different approaches as non-structural measures such as emergency rescue to evacuation centres, removing populations and urban infrastructure from flood risk sites through resettlement, incorporating engineering measures through structural measures such as excavating drainage channels – complementing one another through integrated actions in line with Bertilsson et al. (2018), Liao (2012), and Vitale et al. (2020). This study helps broaden the scientific understanding of resilience to floods and to natural disasters in general, as it shows that there is a possibility of promoting resilience even in contexts of limited or insufficient technical and financial capacity, where capacity building over time through technical institutional competence development and improving the technical quality of staff is a key strategy in promoting socio-ecological resilience, as found by Aldunce et al. (2015) and Brown (2016). However, the study shows that the existence of contrary actions taken by some actors in the territory may compromise efforts to promote resilience. Therefore, the effort to promote flood resilience demands total commitment from local actors such as urban planners, politicians, and community members to cooperate and reinforce actions and measures for improved resilience, based on existing capacities, transforming and expanding local flood response capabilities.

Paper III (manuscript)

Neves, J.L. & Espling, M.: The role of communities in building urban flood resilience in Matola, Mozambique.
Current status: Completed manuscript.

This paper discusses community urban flood resilience in the case of Matola, Mozambique. Community urban flood resilience is a challenge in different parts of the world ranging from those with more resources, such as the West, to developing countries, such as Mozambique, with a mostly needy urban population, especially in communities under financial and livelihood constraints. Matola is located on a coastal plain in the catchments of the Matola and Infulene rivers. In 2000 Matola was hit by floods that destroyed economic and social infrastructure and assets and caused casualties. Considering the 2000 floods and their aftermath, the study looks for answers about community actions, measures, and strategies of flood adaptation and mitigation taken so far. The aim is to find out what measures and actions the communities in Matola have developed to cope with urban flooding since the 2000 floods, and to analyse these from a community resilience perspective. The study is based on 18 in-depth interviews and three focus group interviews with 24 citizens living in risk areas and who experienced the 2000 flood, and on observations in the field.

The findings reveal that community mitigation actions during the 2000 floods in Matola consisted of reinforcing the material structure of the housing, installing water barriers at house doors, sealing backyards with walls of sandbags, and rescuing and accommodating community members besieged by floods. After those floods, in addition to improving housing conditions and raising yard levels with fill, new homes were built either in resettlement sites or in relatively safe self-obtained sites, which changed the environment of community members. Contributions of small sums of money in small groups, helped to purchase some basic items such as food and blankets. The study reveals that social capital, characterized by pre-existing strong community relationships of cohesion and mutual trust rooted in local practices and customs, was a crucial mitigating and recovery factor during and after the 2000 floods. This cohesion and mutual trust between members of Matola's communities favoured people come together to support and rescue community members besieged by floods, as well as in the housing reconstruction process after floods, as found by Bulti et al. (2019) and Vitale et al. (2020). Strong social cohesion is important for community resilience, as the existence of social networks and local organizations is linked to a community's well-being following a disaster and can help overcome financial and material limitations among members through mutual aid, something found by Twigg (2009), Vitale et al. (2020) and Wickes et al. (2015). However, this cohesion has been lost in recent years, particularly due to urban growth in Matola, which has brought new residents who do not care about integrating socially with the older residents. This raises great concern on the part of older residents and local community leaders, as they recognize the importance and usefulness of unity, trust, and cohesion for mutual support in times of crisis, as occurred in the 2000 floods.

The findings reveal that community collaborative action with the municipality facilitated the rescue of flood-struck communities, house reconstruction and food assistance, identification of the main waterways for excavating drainage channels, and the resettlement process. Collaboration consisted of creating teams of community members with urban planners and rescue teams to locate and rescue families besieged by floods. Collaborative actions also consisted of creating work teams that community leaders were part of, for the purpose of identifying families to be resettled, settlement locations, and basic needs and construction materials so families could return to their homes. This was challenging due to their limited financial and livelihood conditions and the urban management constraints affecting them. However, this study shows that collaboration between community members and municipal entities in times of flooding is a strong recovery factor, improving and stabilizing family life in contexts of limited resources, in line with Bulti et al. (2019) and Twigg (2009).

In addition to direct collaboration between communities and municipal entities, or between planners and rescue teams during the 2000 floods, indirect collaboration between the municipality and communities via locally elected community leaders is also practiced in Matola. These represent communities at the municipal level, transmitting concerns regarding community issues to municipal entities. However, when necessary, municipal representatives, such as urban planners or the municipal president, hold meetings with community members to discuss specific issues, such as flooding in a certain area.

However, the promotion of community resilience to flooding also faces challenges related to occupations of floodable areas by housing and commercial infrastructure, which ends up blocking water in rainy seasons, and flooding portions of neighbourhoods that previously did not flood. This reveals the need to increase relations between communities and the municipal administration, to prohibit the construction of infrastructure in areas of waterways, by raising awareness among residents, and not attributing rights to use land in floodable areas by the municipality.

The knowledge presented in this study contributes to urban planning, to rethinking how to build a resilient society by looking at community characteristics and valuing local community knowledge that may be relevant to the strategies and measures to be implemented. The study also shows the need to pay attention to structural changes within communities, because with the change or increase in population, the perception of risk may change, and community members' flood risk coping strategies and actions may also change. This knowledge can be useful, whether in Mozambique or other similar contexts around the world when addressing community resilience to the impacts of floods and other natural disasters.

8. CONCLUSION

This chapter comprises two sections. The first presents the findings of this study in relation to flood vulnerability and the challenges for urban planning and development in promoting flood resilience in Matola, Mozambique. The second section highlights this study's contributions, implications for future research, and recommendations.

8.1. Flood vulnerability and the urban planning and development challenges in promoting flood resilience in Matola

The overall aim of this thesis is to investigate the challenges of promoting resilience to urban floods in Matola, Mozambique. Matola exemplifies an urban environment in a developing country that suffers greatly from the negative impacts of floods, and where urban planners and managers have difficulties in assessing detailed flood vulnerability and risk and in making risk projections. In the year 2000 there were major floods in Mozambique caused by heavy rainfall, with devastating impacts on Matola. Since 2000, Matola has suffered frequent floods of lower magnitude, caused by heavy rainfall, especially in the hot, rainy season (October–March). At the same time, Matola is experiencing an increase in population, and a markedly horizontal urban growth of various socio-economic infrastructures, with an emphasis on housing.

The existing risk of flooding, associated with difficulties in assessing flood vulnerability and risk, raised the first research question and sub-question, resulting in the first paper. These research questions are: How are flood hazard and risk distributed in Matola in the past, present, and future, considering the various changes in land use, population, and climate-change scenarios? How can flood-risk maps be developed given data scarcity? Furthermore, in a developing country context, as in Mozambique, technical and financial constraints affect mitigation and adaptation measures and actions to develop resilience to flooding in cities. These difficulties in promoting resilience to urban floods are experienced by urban planners and by the communities affected by floods in Matola. This is the background to the second and third sets of research questions, which guided work on the second and third papers, respectively. The second set of research questions is: What flood mitigation actions were taken during the 2000 floods, and what strategies and adaptation measures were used by urban planners to promote flood resilience in Matola? How have urban planners, through urban planning, contributed to building and promoting flood resilience in Matola? The third set of research questions is: What mitigation measures and actions did the communities in Matola adopt to cope with the 2000 floods? How have these communities approached adaptation measures to foster future flood resilience?

8.1.1. The flood risk assessment for Matola for 2000, 2020, and 2040

Regarding flood risk assessment under population growth and urban land use change in Matola, related to the first research question and sub-question, it was possible to develop the flood risk assessment for Matola for 2000, 2020, and 2040 based on GIS, using the TFM-DYN hydrological model with the accessible ArcGIS 10.5.1 technology. ArcMap v10.5.1 (with Spatial Analyst) and Python v3.4 software were used to process the input, combining a digital elevation model with data on land cover, rainfall, infiltration, and surface roughness, to analyse the results, and visualize the resulting maps of flood vulnerability, highlighting the variables of water depth and flow velocity for Matola in 2000, 2020, and 2040.

The findings reveal that, overall, most of the Matola area faces very low flooding risk, and areas facing the lowest-depth (0–0.01 m) flooding risk accounted for 49.4% of the area in 2000, 57.7% in 2020, and 62.4% in 2040, affecting about half the population in each year. These are areas of very low or almost nonexistent flood vulnerability, as their population and infrastructure are not exposed to the direct impact of flood disturbance. In turn, the medium- and high-flood-risk areas put many inhabitants in a vulnerable situation, although fewer than those in the very-low- and low-risk areas. In 2000, 61,978 inhabitants were exposed to medium risk of flooding in an area of 50.6 km2, and 53,037 inhabitants were exposed to high risk in an area of 43.3 km2. In 2020, 130,628 inhabitants were vulnerable to medium risk of flooding in an area of 44.8 km2 and 92,723 inhabitants were vulnerable to high risk in an area of 31.8 km2. In turn, in 2040, 203,100 inhabitants may face a medium risk of flooding in an area of 39.0 km2, corresponding to 10.6% of the area, and 151,169 inhabitants may face a high risk in an area of 28.9 km2. These findings show an increase in the extent of low-risk areas of flooding, and a decrease in the extent of medium/high-risk areas from 2000, through 2020, to 2040. However, the findings reveal an increase in the number of inhabitants exposed to combined medium/high-risk areas of medium/high-hazard classes of flooding ranging from 0.5 m to approximately 5 m in depth, due to the increase in markedly horizontal land occupation by socio-economic infrastructure, particularly housing. The findings indicate that the hydrological modelling methodology presented here – i.e., creating maps showing maximum water depth, velocity, and risk in Matola in the past, present, and future despite data scarcity – could be useful for other cities in Mozambique or elsewhere, especially in developing countries for the same purposes.

One issue in developing countries is rapid urban growth: in only a few decades, these countries have gone from being mainly agricultural to having large industrial and urban sectors. In many instances, the flood and water management systems have not kept pace with this growth and can lag the land use and urban development by years or decades, as found by Douglas (2018) and Muis et al. (2015). Therefore, such a risk assessment methodology would be very useful, especially in developing countries, supporting the development of flood management systems that consider flood risk assessment results of the past, present, and future; physical phenomena/processes such as rainfall and terrain; and people, economic, social, and environmental assets in the floodplain. As in this study, it seems like a scientific adventure to conduct a prospective risk assessment, as there are uncertainties because the results represent only what could happen according to the input data, and the results are difficult to validate. However, as argued by Alfieri et al. (2014), EU (2018), and Xu et al. (2021), assessing the risk of flooding and including projections of future scenarios is necessary. This is because flood risk management requires efforts associated not only with the zoning of flooding hazards, but also with flood risk management strategies that combine hazard exposure and social vulnerability, and also concerning how to build the resilience capacity now and in the future.

There is clearly a need to produce reliable vulnerability and flood risk data for the past, present, and future, and this study sought to do so. As argued by Luu et al. (2020) and Nogherotto et al. (2019), in studies assessing flood vulnerability and risk, one possible method of flood-model validation is to compare model output with data from real events, such as remotely sensed images taken during flood events and/or reports of the number of affected people. Thus, this study can be verified not with remote sensing images, but by the similarity between the modelled and real affected populations in the 2000 floods, as follows. In this study, the findings reveal that the total numbers of inhabitants vulnerable to medium (61,978.4 inhabitants) and high flood risk (53,036.8 inhabitants) corroborate results published during the 2000 floods by GFDRR et al. (2014) and ReliefWeb (2000), indicating that in Matola, an estimated 100,000 people were affected by the floods. This gives some credibility to the present results, based on Pilesjö and Hasan's (2014) TFM-DYN hydrological model. The present flood risk assessment results for Matola in 2000, 2020, and 2040 fill the gap highlighted by Aerts et al. (2014) and Muis et al. (2015), that probabilistic estimates of current and future urban flood risk are especially rare for developing countries such as Mozambique. The results of flood risk assessment for Matola in 2000, 2020, and 2040 are data that are relevant for urban planning activities, to incorporate mitigation and adaptation measures that respond to the exposed risk scenario, with a view to making Matola flood resilient. This proposed methodological approach to assessing past, present, and future flood risk can be used in studies assessing vulnerability and flood risk in other parts of the world. This study, with this approach to assessing past, present, and future flood risk, remedies the insufficient attention paid to the projected spatio-temporal transformations of land use generated by socio-economic development by the flood risk projection community, as stated by Hinkel et al. (2014) and Muis et al. (2015). By carrying out such risk assessment, urban planners, urban managers, and/or flood risk managers may be taking the significant steps necessary to manage the risk of flooding. The results of risk assessment can support the choice of mitigation and adaptation measures and actions, and better prepare urban systems for resilience to future flood shocks.

8.1.2. The role and challenges of urban planners and communities in promoting flood resilience in Matola during and after the 2000 floods

The findings related to the second set of research questions regarding what flood mitigation actions were taken during the 2000 floods, and what strategies and adaptation measures were used by urban planners and through urban planning to build and promote flood resilience in Matola, show that the mitigation actions during the 2000 floods focused on the evacuation and accommodation of people besieged by the floods. These activities were carried out by urban planners in coordination with community members, agents of INGC, other employees of public and private establishments, as well as students who were available as volunteers to support the effort. After the 2000 floods, adaptation measures were strategically implemented by gradually supporting the return of community members to their residences, resettling households whose previous homes had been permanently flooded and residents of areas at high risk of flooding, and excavating drainage channels. A major strategy of the municipal administration to promote and build flood resilience in Matola after the 2000 floods was capacity development through training staff, and through the gradual hiring of new staff from different specializations, essential for planning and managing the city in view of the flood hazard. This strategy allowed for the formulation of partial plans specifically addressing flooding issues and a new urban plan in 2010 addressing, among other aspects of urban development, the problem of flooding, identifying areas vulnerable to flooding and specifying waterways, green and protected areas, and other urban features. Based on this information, and with material and financial support from the Municipality of Matola, it was possible to gradually implement flood resilience spatial solutions, such as removing people from flood-prone areas and relocating them to safe areas, specifying areas destined for urban agriculture and housing infrastructure, and constructing drainage systems and bridges – among other fundamental infrastructure for the urban fabric in the context of promoting flood resilience. Institutional capacity development to better address measures and actions promoting flood resilience in Matola is a practical example in a developing country that supports the approach of socio-ecological resilience that previous studies have noted (e.g., Aldunce et al., 2015; Brown, 2016), namely, that resilience in the socio-ecological system is a learning process characterized by the improvement of adaptation capacity and the ability to adjust to change.

The findings also show that the central government takes action by creating laws (e.g., Law No. 19/2007 of 18 July – Spatial Planning Law; Law no. 15/2014 of June 20th – Legal Regime for Disaster Management, translated from Portuguese) and plans/strategies (e.g., National Climate Change Adaptation and Mitigation Strategy for 2013–2025, MICOA 2012, translated from Portuguese) intended to regulate sustainable land use and guide the promotion of resilience to disasters resulting from climate change impacts, one of which is flooding. Such actions also include creating institutions and equipping them technically and materially, for example: INAM, the National Institute of Meteorology, releases weather forecast information for the next 24 hours across the country; DNGRH, the National Water Resources Management Directorate informs Mozambicans of the impact of the forecast weather on waters in the national river basins (translated from Portuguese). These support the promotion of resilience to floods, not only in Matola, but across the national territory.

However, several challenges undermine the promotion of flood resilience in Matola, such as population growth and accelerated and markedly horizontal urban development that, as Araujo (2003) noted, exceeds the municipal capacity to monitor water and flood management systems across Matola. The rapid urban growth also exceeds the municipal capacity to maintain existing drainage channels and roads due to financial, material, and inspection personnel constraints. These financial and technical constraints have been highlighted in previous studies (e.g., Andreatta & Magalhães, 2011; Artur & Hilhorst, 2012; Broto et al., 2015) as among those that undermine the promotion of resilience in Mozambican cities. In addition, the findings reveal that there is insufficient coordination of adaptation actions among urban planners and political elites due to cases in which places vulnerable to flooding are occupied by housing and commercial infrastructure by citizens with land use right licenses (DUATs) granted by the Municipality of Matola through the influence of political leaders. These findings support previous findings of Douglas (2018) and Nkwunonwo et al. (2016), about promoting flood resilience in developing countries. Their findings pointed out that urban flood alleviation strategies in many developing countries have not succeeded because of the complex alliances that exist between different actors such as politicians, parties, and stakeholders due to their need to satisfy supporters occupying urban land in strategic places, often floodable. Furthermore, the present findings confirm previous findings about promoting flood resilience in Mozambique (e.g., Andreatta & Magalhães, 2011; Artur & Hilhorst, 2012), that while urban planners take the adaptation agenda seriously, political interests concerning, for example, land tenure issues, undermine urban development adjusted to adaptation and/or mitigation actions. To add to the list of actions that challenge the promotion of flood resilience in Matola, members of low-income urban communities, in turn, occupy floodplain areas, forming disorganized and informal urban housing areas that counter resilience-building actions. With the growing threat of flooding, it becomes very complex to address urban flood resilience in Matola, a complex urban socio-ecological system, in the face of a lack of technical and financial capacity, which was also found by Bunce et al. (2010), Douglas (2018), Gupta (2020), Nkwunonwo et al. (2016), and Owusu and Obour (2021) in other developing countries and regions facing similar challenges.

The challenges of addressing urban flood resilience in Matola shows the power of the actions of social actors combined with the level of resource availability, favouring or constraining social reproduction. Therefore, mitigation and adaptation measures and actions developed by urban planners to promote flood resilience in Matola were carried out in the face of some contradictory actions to promote urban resilience by some politicians and community members. However, urban planners, within the existing collaboration with local actors (e.g., politicians, community members, and other stakeholders) and given the technical and financial constraints, sought to address mitigation and adaptation measures and actions, prioritizing what was technically and financially possible. Therefore, the actions of urban planners helped to reduce the exposure and vulnerability to flooding of the population, assets, and urban infrastructure, as well as improving ecosystem services (e.g., accumulation of rainwater, rainwater runoff, and recovery of natural flora and fauna habitats) in the low-lying areas and protected coastal wetlands.

Despite the difficulties, the findings show that promoting resilience to floods in Matola takes place within overall socio-ecological resilience, in line with Liao (2012), Norizan et al. (2021), Vitale et al. (2020), and Wamsler and Brink (2014), incorporating: engineering or structural measures such as excavating drainage ditches; non-structural measures such as resettlement by removing urban infrastructure from flood-risk sites and letting areas perform their ecological floodplain function; and early-warning and emergency measures such as emergency rescue to evacuation centres and temporary shelters and the adaptation of individual houses. These measures and actions were taken to maintain and reinforce a sustainable relationship between the social and biophysical environments of Matola, as argued by Brown (2016) and Cooke et al. (2016), to safeguard the existing interrelationships between social and natural systems. Furthermore, improving the adaptive capacity was a central strategy in the Municipality of Matola, particularly in the urban planning sector, aligned with the assumptions of promoting resilience in the socio-ecological system, as stated by Aldunce et al. (2016) and Brown (2016). This includes reviewing the capacity of people and the structure of organizations associated with disaster risk management, based on what did and did not work during past disasters.

The third set of questions focuses on mitigation measures and actions the communities in Matola adopted to cope with the 2000 floods, and how the communities have approached adaptation measures to foster future flood resilience. At the community level, the study reveals that during the 2000 floods, social capital, characterized by pre-existing strong social cohesion and mutual trust among community members, was vital for people to come together to support and rescue community members besieged by floods. The communities also collaborated with the municipality in forming joint rescue teams during the 2000 floods, and accommodating flood victims in prepared accommodation centres was one of the fundamental mitigation actions. Furthermore, monetary contributions channelled through pre-existing mutual aid practices among community members helped to meet some basic needs of community members during the crisis caused by the floods. Community adaptation measures after the 2000 floods were the improvement and reconstruction of houses destroyed by the floods, raising land levels with fill to reach above previous flood levels, adherence to the resettlement scheme promoted by the municipality, and the resumption of business and agricultural activities, among others, all of which helped improve the communities' livelihood conditions. As previous studies have noted, community attributes such as local social capital and social cohesion are extremely important for community resilience, which Bulti et al. (2019) saw as one of the key dimensions or properties promoting community resilience. Importantly, the availability of social cohesion, social networks, and local organizations associated with the technical and financial capacity of communities increases adaptation abilities and the likelihood of creating and improving community well-being following a disaster, as argued by Wickes et al. (2015) and Vitale et al. (2020).

However, the findings show that the communities face new challenges that serve to undermine the promotion of flood resilience, such as: decreased social cohesion due to new residents not integrated in the network of pre-existing local relationships; infrastructure built in flood-prone areas by new residents, despite the warnings of neighbourhood leaders and those who experienced the 2000 floods; and residents throwing rubbish into drainage ditches, blocking water flow and causing flooding in certain areas. The temporal-spatial continuity of pre-existing power relations, mutual trust, and cohesion in social systems is essential for promoting resilience. However, as suggested by Giddens (1984), such continuity presupposes the existence or creation of regularized relationships in which actors or collectives feel autonomous and dependent on these networks of relationships in contexts of social interaction, and thus maintain and protect them. Therefore, it may be possible to unite people in Matola's communities through elements that bring their interests together, by means of possible regular and structured elements or rules, to the point of not allowing social cohesion among local members to fade. How to do this would be the subject of another study.

The findings also show that the municipality's official administrative structure was an important network for collaboration with communities, represented by their elected leaders, in promoting community flood resilience because it favoured organizing the resettlement process over time after the 2000 floods. In the resettlement process, activities consisted of identifying families to be resettled, choosing the best place to resettle, and continuing to support families with basic goods until housing was allocated to those covered by resettlement. As highlighted by Twigg (2009), the level of a community's resilience is also influenced by capacities outside it, in particular by the capacities of disaster management services and other public administrative and social services. However, as noted by Bulti et al. (2019), this depends on the effectiveness of relationships within the community and between it and the public administration or other entities.

Concerning community collaboration with the municipality, the results show that there are challenges to be overcome due to the relatively weak participation of communities in decision-making and actions within the municipality. Until now, community participation in urban management has occurred when planners need help with local knowledge, to inform communities about what is being done by the municipality, to consult communities about actions to be developed, and even when communities go to the municipality to present concerns, which sometimes are not integrated into subsequent actions. However, as Cornwall (2008) noted, participation needs to be improved to become interactive, with participation being seen as a right, not just the means to achieve project goals by having people participate in joint analysis, the development of action plans for urban flood management, etc., and strengthening local institutions.

8.2. Contributions, implications for future research, and recommendations of the study

This study was carried out to identify fundamental stages of the natural risk management process, or disaster risk reduction, which involved assessing the risk of flooding and identifying which strategies, measures, and mitigation and adaptation actions are being developed to promote resilience to urban flooding in Matola. DRR policies, strategies, and programmes are intended to build resilience based on adaptation and mitigation measures, and they include risk assessment targeting risk drivers (UNDRR, 2009, 2019b; Wisner, 2003). This approach to academic research is fundamental to this type of case study, because in addition to producing scientific knowledge, the results can be used as data to plan the development of measures and actions to promote resilience in the studied location.

The data from the flood vulnerability and risk assessment, and from investigating resilience strategies, measures, and actions, are also fundamental tools in managing associated risks, helping make decisions, and choosing the flood adaptation and mitigation strategies, measures, and actions to be developed to promote resilience to floods. The data from the flood vulnerability and risk assessment, and from assessing resilience strategies, measures, and actions, also serve as a basis for awareness of the current scenario, of the decisions taken previously that led to the current scenario (Priest et al., 2016; Smith, 2013; Song et al., 2019; EU, 2018). This information base makes it possible to plan and project the desired sustainable urban development through short-, medium-, and long-term resilience-building strategies. These can be realized through measures and actions, also in the short, medium, and long terms, applied in different fundamental areas to build a sustainable urban fabric and promote the well-being of the city and the local population.

This study helps reduce the research gap concerning specific urban area scenarios of future hazard and flood risk noted in previous studies. According to Hinkel et al. (2014) and Muis et al. (2015), the projected spatio-temporal transformations of land use generated by socio-economic development have received little attention in the flood-risk-projection academic community. Therefore, this study may serve to inspire the academic community concerned with flood risk assessment and management, urban planners, and territorial managers in general to develop similar flood risk and vulnerability assessment studies that look at the past, present, and future.

This study builds an understanding of the role of urban planners and community members in the process of promoting flood resilience in Matola, by showing what worked, for example, gradually increasing technical capacity, designing new urban plans, and cooperation between community members and planners in rescuing and resettling families. Additionally, the study supports previous studies, especially in developing countries, finding that social capital, characterized by social cohesion and mutual trust, is fundamental as it allows collaboration among community members so they can face flood hazards with a greater probability of success, and not just wait for and depend on official government aid. This study illustrates that the existence of some actions countering efforts to promote resilience can undermine coordination, cooperation, and mutual trust among social actors (e.g., urban planners, community members, politicians, and other stakeholders), which are fundamental factors in promoting flood resilience. How can these social actors work together with institutions in promoting resilience for the common good, without actions countering their efforts in Matola? This could be the subject of another study.

This study also shows what did not work properly, such as allocating DUATs to citizens who then build in areas prohibited by national and municipal environmental standards because they are rainwater channels; this building ends up blocking the water flow, causing flooding in places that would not be flooded if there were no such barriers. Another threat is the reduction in social cohesion due to the increasing urban population in Matola from 2000 to the present, which may weaken community ability to face future hazards collectively. This implies seeking to integrate new residents in networks of pre-existing relationships, or finding other ways to create cohesion and mutual trust among residents of Matola neighbourhoods. What would these paths be? Are there any factors other than new people moving into the neighbourhoods that have affected such cohesion? This could be the subject of another study.

Furthermore, the study identifies what needs to be improved, for example, raising awareness among citizens, prohibiting the construction of infrastructure in areas that are waterways, and monitoring to ensure politicians' improved compliance with environmental standards by not allocating DUATs to citizens in flood-prone areas or waterways. Furthermore, promoting environmental education on the problems to be faced, such as floods, would contribute significantly to ensuring that actors and structures in the territory follow plans and actions that promote resilience in the socio-ecological system. Such measures are necessary since an urban planning framework for promoting and building flood resilience should be developed based on the awareness, social organization, and empowerment of the community to cooperate with urban planners in urban planning and development. Such cooperation should be based on the effective participation of social, political, and economic actors, to make decisions or better proposals for the promotion and increase of flood resilience for social, economic, and environmental welfare today and in the future.

All the challenges described above put Matola, as well as other Mozambican municipalities, in the same situation, facing an obviously uncertain future of extreme events related to climate change, such as intense tropical cyclones, heavy rainfall, and consequent flooding. Such events illustrate the need to mobilize increasingly more financial, technical, and material resources from the municipalities, national government, and interested stakeholders with which to face these challenges, developing actions and measures that guarantee the adequate functioning of urban services, and satisfy the increasing demand for urban land while ensuring and consolidating the promotion of resilience. The ability of a society to successfully face future shocks without losses and much damage depends not only on the existing conditions, but also on the paths to promoting resilience that have been tried so far.

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