# Livelihood strategies to address water induced vulnerability on marginal settlements. Lessons from Northern Mozambique and Mumbai

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** Anubhav Goyal is CIAUD, Research Centre for Architecture, Urbanism and Design, Lisbon School of Architecture, Universidade de Lisboa*
*urbtext@gmail.com*
*ORCID: http://orcid.org/ 0000-0002-1364-2681*

**Joana Pereira is cE3c, Centre for Ecology, Evolution and Environmental Changes, Faculty of Sciences, Lisbon University*
*jgopereira@fc.ul.pt*
*ORCID: http://orcid.org/0000-0002-8103-5496*

***KEY WORDS:***

*Adaptation / Marginal Settlements / Resilience / Vulnerability / Water*

***ABSTRACT:***

*Increase in water induced risks are realized with marginal settlements being more vulnerable due to limited adaptive capacity. The challenge put forward by climate change, in absence of adequate formal strategies, has forced the dwellers of marginal settlements, over the years, to adopt local adaptation strategies to survive the risk and live in harmony with water. The highly diverse characteristics based on livelihoods and social networks provide for adaptive capacity of the dwellers. The objective of the paper is to identify these strategies based on livelihoods or the daily activities of the dwellers within the marginal settlements in different territories. Rural marginal communities in Northern Mozambique and urban in Mumbai are assessed by direct observations, interpretation from collected images and literature review to present a framework of strategies based on livelihoods. Result provides for holistic findings that contribute to the lexicon of water-risk adaptation for marginal settlements in developing countries.*

# 1 INTRODUCTION

Climate change and disasters are currently the greatest global threat and defining challenge of the 21st century. If the current rate of global warming continues, the world could be 1.5 °C warmer by 2030 (IPCC, 2018). Changes in weather and recurring extreme events are realized to increase, including water induced risks such as extreme high sea levels, extreme precipitation events, floods and water scarcity along with decline in water quality. Coastal regions, in developing south, are facing severe floods from intensified precipitation, cyclones, storms and sea level rise. Regional warming could be twice the global average in certain places, which means that at least 136 coastal cities will be at risk from flooding, and in the process, affect 280 million people including many informal settlements (IPCC, 2018) and marginal groups. Roughly 110 million people currently live on land below the high tide line. Based on the sea level projections for 2050, land currently home to 300 million people will fall below the elevation of an average annual coastal flood. On the other hand, prolonged drought periods are resulting in reduced water supplies that often lead to water insecurity and severe food shortage. Thus, water presents significant risks, with marginal settlements being more vulnerable due to limited capacity to absorb and prevent the water induced risks. As a direct cause, the physical location of the marginal settlements in the developing countries, makes them at a greater risk. Further, the water induced risks are disproportionately affecting social, economic, cultural, political and institutional aspects of the marginal communities. Such communities, whether in rural or urban territories, have limited adaptive capacity due to their economic status and lack of access to public services and infrastructures thereby making them more vulnerable to climate hazards than dwellers in the non-marginal part of the cities. Also, marginalized communities are much more dependent on ecosystem services such as food and water, disease control, economic and cultural services, which makes them much more sensitive to climate variability with serious consequences for their livelihoods.

## 1.1 Livelihood vulnerability to water-induced risks

According to the Livelihood Sustainable Framework (LSF), a livelihood comprises people, their capabilities and activities required for means of living as well as their access to assets - both material and social resources (Chambers & Conway, 1991). Such assets are put in use through certain strategies and activities to achieve desirable livelihood outcomes. Livelihoods are sustainable when they can cope with and recover from stress and shocks, maintain and enhance their capabilities and assets, and provide sustainable livelihood opportunities for the next generation (Chambers & Conway, 1991). Therefore, livelihood vulnerability depends on the asset base that people have prior to the hazard and their ability to engage in various coping strategies.

The concept of vulnerability has been traditionally centered on the impacts of climate-related stressors on human societies and on determining their ability to cope and adapt to such risks and hazards in order to evaluate societal resilience (Adger, 2006, Eakin & Luers, 2006). Vulnerability was defined by IPCC (2007) as "the degree

to which systems are susceptible to, and unable to cope with adverse impacts [of climate change]". Vulnerability can be assessed in three dimensions: 1) exposure, i.e., nature and degree to which a component is in contact with, or subject to, a stressor or driver of change (IPCC, 2001, Thiault et al., 2021); 2) sensitivity, i.e., set of conditions determining the degree to which a component is directly or indirectly altered or modified in the short term by stressor exposure (IPCC 2001, 2007; Thiault et al., 2021), and 3) adaptive capacity, i.e., ability to implement effective responses to changes by minimizing, coping with, or recovering from the potential impacts of a stressor (IPCC, 2001, Thiault et al., 2021). Water induced risks come here as a dimension of exposure to which people can be more or less sensitive according to their access to assets and activities and their capacity of adaptation. Water induced risks are classified into four classes of hazards: shortage of water, inadequate quality, excess of water (flooding) and decreased resilience of freshwater systems (Garrick & Hall, 2014). Water induced risks are escalating with the increasing global exploitation of water resources across the world which has led to significant degradation of ecosystems and the goods and services they provide, alongside the impacts of climate change (Orr et al., 2009). Managing water risks to an accepted level is within the definition of water security as a "tolerable water-related risk to society" and it is crucial to safeguard access to water for livelihoods and development, protect against water pollution and water-related disaster and preserve ecosystems (Garrick & Hall, 2014).

## 1.2 Adaptive capacity to water-induced risks

The challenge put forward by climate change, in the absence of adequate formal government strategies, has forced the dwellers of marginal settlements, over the years, to adopt local adaptation strategies to survive the risk and live in harmony with water. It is realized that the marginal settlements present highly diverse characteristics based on livelihoods diversification and social networks that provide adaptive capacity for the dwellers. How marginal vulnerable groups prepare and respond to water induced risks, over the years, plays a significant role in building the adaptive capacity and in providing sustainable livelihood in the light of limited formal assistance. For instances, rural communities in Northern Mozambique are very vulnerable to climate variability due to the increase of floods, cyclones and the high dependency on rain-fed subsistence agriculture. The decline in agricultural production and the uncertain climate significantly affects food and water security. Seasonal migration, diversification of livelihoods and the role of social networks in enhancing livelihoods security are some of the coping strategies to water risks adopted by these communities. On the other hand, marginal communities in Mumbai are mostly located in low lying areas close to marshes and river lines. These settlements lack basic infrastructure facilities, additionally burdened with no security of land tenure and depend on the informal economy for their livelihood. Such neglected settlements are frequently flooded during the monsoon season. The communities comprise local adaptation strategies based on livelihoods from different communities such as fishermen in Koliwada, potters in Kumbharwada, washermen in dhobi ghats, papadwalas, etc.

## 1.3 Water induced vulnerability framework

To understand the diversity of informal capacities emerging from marginal settlements, we selected two case studies and assessed their adaptation strategies by direct observations and interpretation from collected images and literature review from the previous published researches. We selected marginal communities in different types of territories – urban and rural - with similar contributing vulnerable factors such as settlement's characteristics, lack of access to infrastructures and low support from government which increases exposure to water-risks. We aim to present a framework of local adaptation strategies based on livelihoods or the daily activities of the dwellers within the marginal settlements for building resilience to water induced risks. The assessment of informal adaptation strategies in urban and rural communities enable holistic findings and lessons that contribute to research into the lexicon of water-risk adaptation for marginal settlements in developing countries of the global south (Fig. 01). Finally, we will add to the understanding of how adaptive capacity at the local level can be supported through wider water management processes at both urban and rural scale.

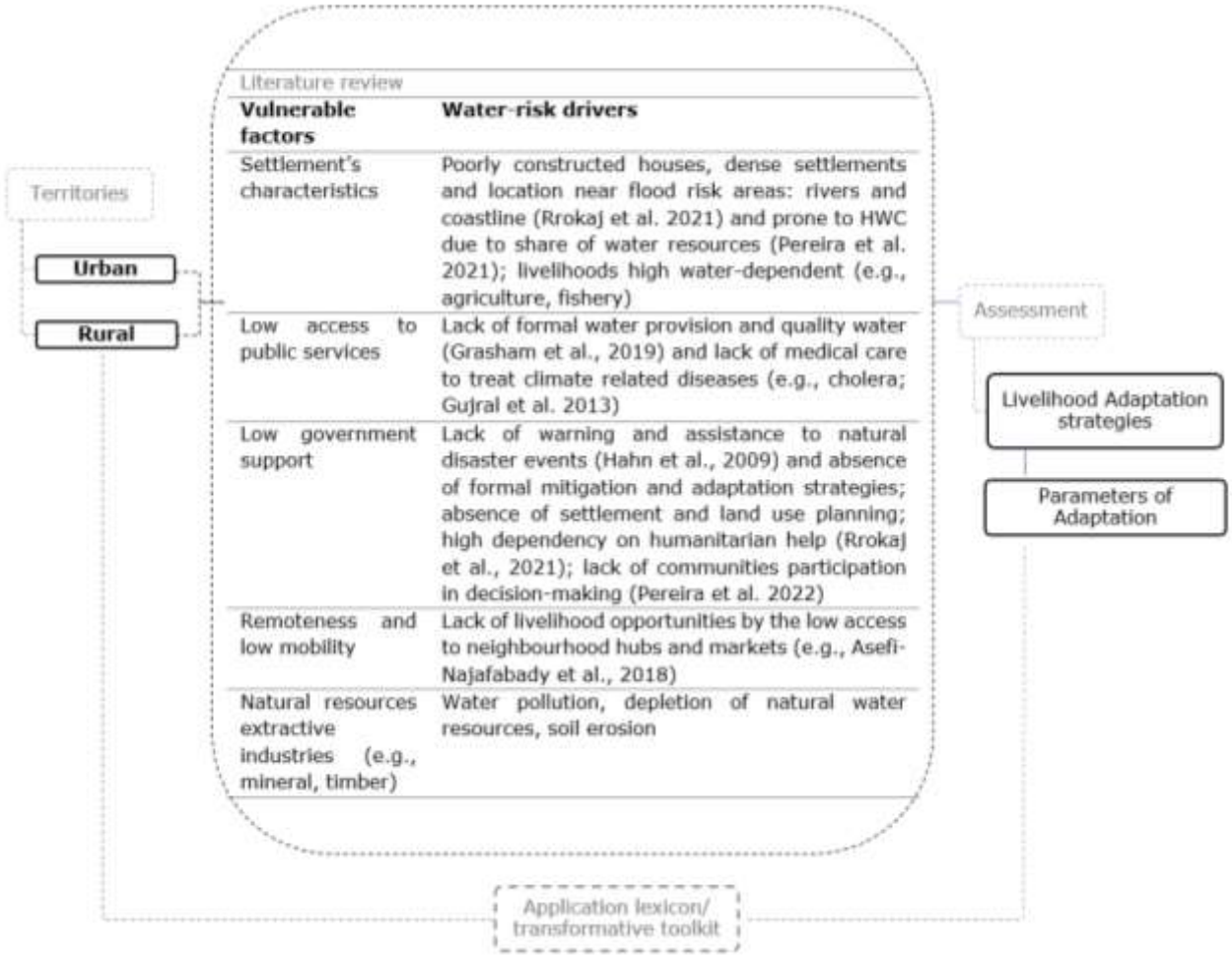



Figura 1. Research map for rendering future marginal communities water risk resilient (Authors).
Fuente: Elaboración propia.

# 2 METHODS

These marginal communities in both the territories; rural and urban, inherit unnoticed local water-risk adaptation strategies that can be exploited as a creative laboratory, to serve the purpose of providing solutions, through an ongoing learning process that may serve to provide future decisions towards addressing water induced risks for marginal groups. Acknowledging the water induced risks, the paper identifies, categorizes and presents local adaptation strategies based on livelihoods or the daily activities that the marginal groups adopt based on the learning and experiences of the past events. These strategies are categorized in accordance with different water-induced risks such as extreme high sea levels, extreme precipitation events, floods and water scarcity along with decline in water quality etc. in different territories. Together, they are not meant to offer an exhaustive collection but rather a significant holistic framework of strategies that endorse further reliable research and decision making.

The methodology applied for the development of this paper has exploratory and investigative character. The design of the research method is based on the observations and interpretations from the marginal communities from the assessed cities. Rural marginal communities in Northern Mozambique and urban marginal communities in Mumbai are assessed for identification of the local water-risk adaptation strategies that marginal groups adopt. The identification of the strategies is done through case study analysis approach by direct observations and field visits at the sites through interpretation from collected images, literature review from previous published researches aiming to present a framework of local adaptation strategies that not just signifies the adaptation capacity of the marginal groups but also contribute to research towards a lexicon of water-risk adaptation for the most vulnerable marginalized groups. Also, the identified strategies are presented in cross-sectional drawings derived from the assessed cases. The drawings that are derived from computer aided design – CAD illustrate the employment of the strategies that operate at different sites; in private or public space; and in different scales; individual, neighborhood or city scale, that form a significant part of the urban spatial form within the marginal communities. Sections are drafted, using the same representation criteria: black line for the built environment and red line for the adaptation strategies adopted by the dwellers in each territories that were studied. Therefore, interpretative morphological drawing is used to decode and reveal the adaptation strategies in the assessed cases.

# 3 LITERATURE REVIEW

## 3.1 Northern Mozambique, Quirimbas National Park

### 3.1.1 Environmental setting and water risks

The Quirimbas National Park (QNP), located in Mozambique's northernmost Cabo Delgado province (-12º30'0 S, 39º24'0 E), was established in 2002 and it is considered a global priority for conservation of biodiversity (MITADER, 2012; Fig. 02).

It is a coastal area with a total of 9,130 km2, comprising terrestrial, marine and island habitats. Cabo Delgado is the poorest province in the country (Smits, 2016) and has the highest number of people living under vulnerable conditions. Besides, the area is highly susceptible to sea-level rise and to the incidence of natural disasters, being one of the areas most prone to flooding and cyclones in the world (Costa et al., 2016). The most recent events, were a severe drought during 2015-2016 and the hit of the destructive Cyclone Kenneth in 2019 which led to the displacement of thousands of people together with crop loss, destruction of infrastructure, assets and livelihoods (Mugabe et al. 2021). Climate previsions indicate that precipitation will increase by 15% and temperature by 3ºC in the next 40 years (Costa et al., 2016). Freshwater availability on mainland is also facing drastic reductions due to long drought periods and seawater intrusion in the underwater reservoirs which affects agriculture production and the use of water for livelihood activities (Costa et al., 2016). Also, the oil & gas, and mining exploitation around QNP is polluting the water sources and contributing to decrease water quality (Costa et al., 2016).

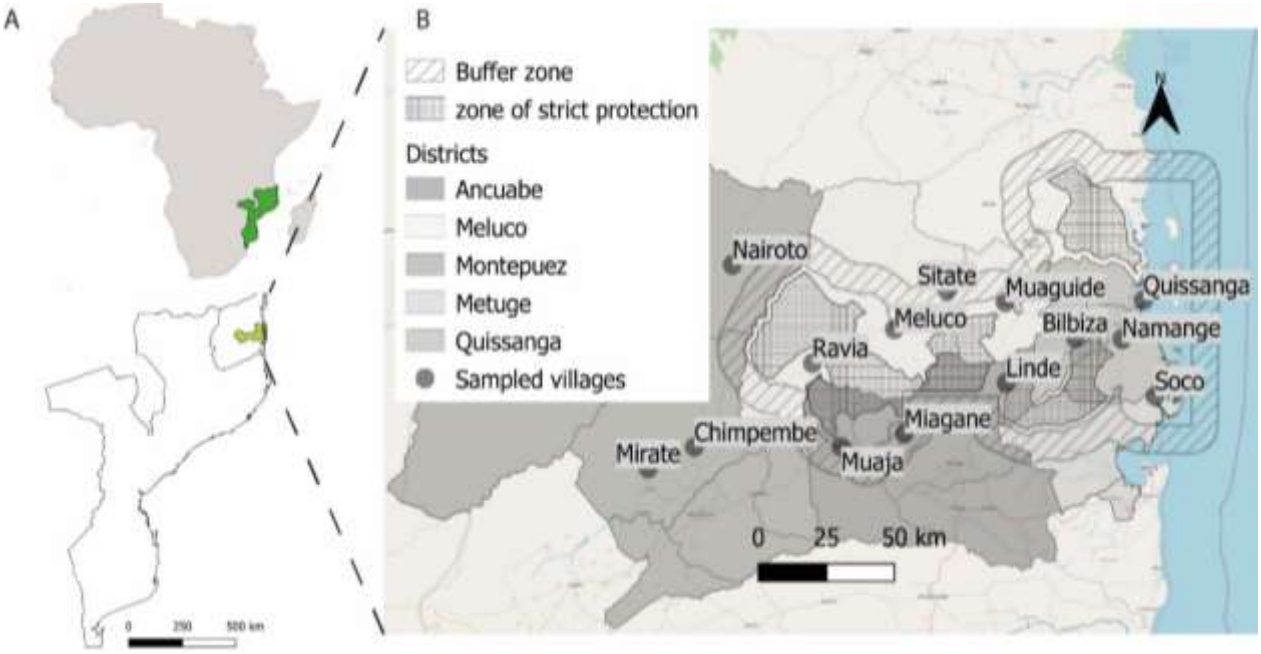



Figura 2. A) Location of Quirimbas National Park (QNP) in the Republic of Mozambique on the African continent. B) Villages within and close to QNP sampled
Fuente: Pereira et al. 2021 from which in-person observations and interpretations were taken for this article (Authors).

### 3.1.2 *Socio-Economic Context and livelihoods vulnerability*

A total of c. 200,000 people are living across 153 villages within the park (Mucova et al., 2018) and have been directly and indirectly impacted by such climate hazards. These communities lack employment opportunities and are extremely dependent on natural resources for livelihoods, through mostly itinerant agriculture, forestry, small livestock and fishing. Choices of livelihood activities are very dependent on ethnicity. The majority of the population in the park are Makua that depend almost exclusively on agriculture. Along the coast line, the population is mostly Kimwani, whose main

yield comes from fishing, and in the north there are some Makonde communities, which are specialized hunters with bow and arrow, responsible for most of the poaching activities in the park (MITADER, 2012). Most communities are strong Islamic (Brouwer & Mabunda, 2005), with Catholicism as the second religion (INE, 2017). The poverty index ranges from 33-41% and only 3.3% of the population in Cabo Delgado province have access to electricity and 5% to piped water, 16% are still dependent on a natural water source such as a river, lake, or lagoon, while up to 70% uses traditional wells and public fountains (INE, 2017). Additionally, communities are living within a protected area in proximity to wildlife. Human-wildlife interactions (HWI) are frequent and may cause costs to communities (Ceauşu et al., 2019) through property damage (Lamichhane et al., 2018), competition for resources (Treves, 2009), disease transmission (Blair & Meredith 2018), and human injury or loss of life (Ratnayeke & Manen, 2014). Water availability is an important driver of these interactions. The fact that communities have minimal access to water sources, including wells and boreholes in the villages, increases their need to use the river for more permanent sources of water (Dunham et al., 2010) which is also used by wildlife. Such implies that women and girls, traditionally in charge of water-fetching activities, need to walk distances of many kilometers to reach water sources (Angoua et al., 2018), being thus at higher risk of encounter wildlife. In the annual dry seasons and with longest periods of drought, the competition for water between communities and wildlife is higher, as well as the probability of disease transmission (Anderson & Pariela, 2005). This pattern is especially true in the context of rural communities lacking access to permanent and safe water sources.

## 3.2 Mumbai

### 3.2.1 Environmental setting and water risks

Mumbai, originally a group of seven marshy islands on the west coast of India showcases a significant conflict with water and environmental needs in light of rapid urbanization (Fig. 03). Over the years, the original seven small islands were combined through silting and land reclamation. The region on the whole is low lying, but not flat. Many creeks have silted up or been filled in to support urban development. Extreme precipitation combined with the undulating terrain and inadequate rainwater drainage system result in recurring annual floods. The worst problems occur when heavy rains and high tides coincide. The drainage system of Mumbai was constructed to handle rainfall at the rate of 25mm/ hour. The city is actually subjected to approximately 100mm/ hour which already stretches the existing capacity (Urbz, 2020).

Marginal communities such as slum dwellers, urban poor and homeless are most vulnerable to the water-induced risks. Slum settlements house approximately 55 percent of Mumbai’s population and are mostly located in low lying areas close to marshes and other marginal places (Chatterjee, 2010). Slums in Mumbai are a significant element of urban landscape that inherit diverse communities based on livelihoods. Dharavi that sits in the heart of the city, host about a million population

(WEF, 2016) that face water induced risks such as limited access to drinking water, recurring floods etc. It is common to share water sources and split the bills.

### 3.2.2 Socio-Economic Context and livelihoods vulnerability

Weather flooding or water shortage, marginalized communities are able to address the risks in light of prevailing social networks and vernacular local adaptation. People have managed to create a productive and well-functioning informal livelihoods that operate in the marginalized settlements. The communities based on livelihoods in composed of the Kolis, who reside in Koliwada with most families living from selling fish and related businesses, potters from Kumbharwada, washer men, papadwalas etc. Everyone in Dharavi is busy and productive, this successful live-work paradigm represents Dharavi lifestyle. The informal and organic urban fabric of Dharavi represents an important repository of history and memory for the communities it serves. Each community continually transforms the physical space that vary in characteristics based on the requirement of their livelihoods, also manifesting on the specificities of their adaptation to water induced risks.

Figura 3. Location of Dharavi slum in Mumbai, Right: Dharavi slum along the Mithi River from which observations and interpretations were taken for this article (Authors).
Fuente: Elaboración propia.

# 4 RESULTS AND DISCUSSION

## 4.1 Adaptive strategies assessment for Northern Mozambique

The livelihoods mostly affected by water-risks in rural communities of QNP are agriculture production and household activities. The long drought periods cause water

scarcity and erosion of the soils as well as the emergence of various pests which critically decreases agriculture production and consequently their main source of food and income. Farmers are transitioning from maize production to more drought-resistant crops such as sorghum and millet which were already used by farmers in the past but got replaced by maize because of its taste and high yield potential in normal rainfall years (Thierferlder et al., 2015). So, farmers are taking back traditional crop species, coupled with a diversification of crop types that increases the chances of having some food in very fluctuating years of heavy rains followed by long droughts as well as improving storing strategies of food and seeds for next year (Hahn et al. 2009). Lack of rain and underwater reservoirs also makes communities to migrate to other places or at least to plant their crops closer to river basins. On the other hand, this movement closer to water sources increases the risk of encounters with wildlife. In fact, water scarcity is one of the strongest drivers of human-wildlife conflicts (HWC) in rural areas as it forces people and wildlife to share the same scarce water sources (Pereira et al. 2021). Additionally, a diversification of livelihoods from agriculture to lesser water dependent livelihoods such as livestock herding, small business, mining and tourism and a higher reliance on forest resources for food are some of the strategies used by communities to adapt to the impacts of water scarcity. Also, the strengthening of social networks between households is also a key factor of communities' adaptation as it brings access to a wide and diverse source of information, knowledge and resources, and impels to collective action and trust among the actors (Charles, 2021) that are critical to ensure adaptation to water risks (Baird & Gray, 2014; Fig. 4B-1&7). For instance, it contributes to a better managing and sharing of water resources among community (Faurès & Santini, 2009) through increased communication (e.g., on weather) and also partnerships (Dickson et al., 2016). However, water scarcity and high temperature also impact other types of livelihoods common in QNP as fishery (e.g., species losses, ecosystem collapse), hunting (e.g., species migration, HWC, zoonotic diseases) and forestry (e.g., wildfires, loss of wild fruits and food plants, and timber species). Community-based management approaches fostered by government or NGOs are helping communities to better manage their fisheries and forest resources by implementing rotation systems for fishing (MICOA 2012; WFP 2021) or by reducing slash and burn practices (Cochrane, 2009; Bare et al., 2010) in order to sustainably use the resources that are being heavily impacted by climate change (Fig. 4B-1&7). The housing structures and materials are also adapted to maintain colder temperatures inside the houses however are not resistant to natural hazards such as flooding or cyclones (Fig. 4B-2&3). Instead, they are building informal dams in the rivers (Artur & Hilhorst, 2012) and planting trees as natural barriers in the sea side (Mucova et al. 2021), and making use of their social networks to spread warnings when a storm is coming (WFP, 2021). In the villages, communities are lacking piped water systems so they have a few formal wells given by the government to access the underground water but the majority are dug informal wells which people have been digging deeper and deeper over time in order to reach underwater reservoirs and work as rainwater collection points as well (Costa et al., 2016. People are then using plastic bottles and cane to be able to collect water in such deeper ponds (Fig. 4B-7).

## 4.2 Adaptive strategies assessment for Mumbai

Dharavi in Mumbai presents varied livelihoods embedded within its urban fabric. Water provides for both; opportunities and risks to the livelihoods of the slum dwellers of this slum. Floods are recurring hazard to which the slum dwellers adapt over the years in accordance with their livelihood requirements. Simple short term household strategies are common such as covering the roofs and openings with plastic sheets, raising the furniture, plinth and relocating to the upper floors etc. (Fig. 4A-5&6). Community measures include cleaning the drains, use of dewatering pumps etc. Here, aid through social networks play significant role in the risk reduction. These measures being short term and vernacular are found to be effective during the flood event in the absence of formal government aid. The dwelling units along the waterfront are constructed on wooden stilts with tin and plastic (Fig. 4A-3). The form and elements are the result of the attempt to address the requirement that exist from these vulnerable sites and vagaries of water. The adaptation strategies are identified and presented in table 1.

Another major water-induced risk is inadequate water supply. Urban slums are the product of failed policies, inappropriate regulations and a fundamental lack of political will. They are burdened with no security of land tenure and depend on the informal economy for their livelihoods. In such circumstances, adaptation strategies involving community participation and NGOs plays an important role in establishing community water collection points and toilets resulting in water-induced risk reduction.

| **Territory** | **Water-induced risks** | **Livelihoods** | **Risks** | **Opportunities** | **Adaptation strategies** | **Parameters** | | **Ref. Section** |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Scale | Type | |
| **Urban** | Extreme precipitation<br>Flooding<br>Sea water rise (SLR)<br>Inadequate water supply | Fishery (*kolis* community) | Water pollution | New opportunities of income and shift to more resilient livelihoods | Livelihood diversification | Household | LT | Goyal, 2021 |
| | | | Solid waste disposal | Water provide for source of mobility | Cleaning the water channels | Community<br>Government<br>NGOs | ST | |
| | | | | | Community based fishing | Community | ST | |
| | | | | | Diversifying the livelihoods (Ex. aqua-culture) and creating fish farms | Household<br>Community | LT | |
| | | Potters (*kumbhars*) | Depletion of clay/ shoreline; Rapid urbanization | Marshy swamps provide for clay; raw material for pottery | Relocation | Household<br>Community | LT | |
| | | | | | Shoreline stabilization and protection (Ex. concrete tripods) | Government | LT | |
| | | | Flooding | | Raising of plinths | Household | ST | |
| | | Laundry (Washermen) | Water pollution at ghats, high | Provide for procurement of water and | Creating retention ponds | Community<br>Government<br>NGOs | LT | |

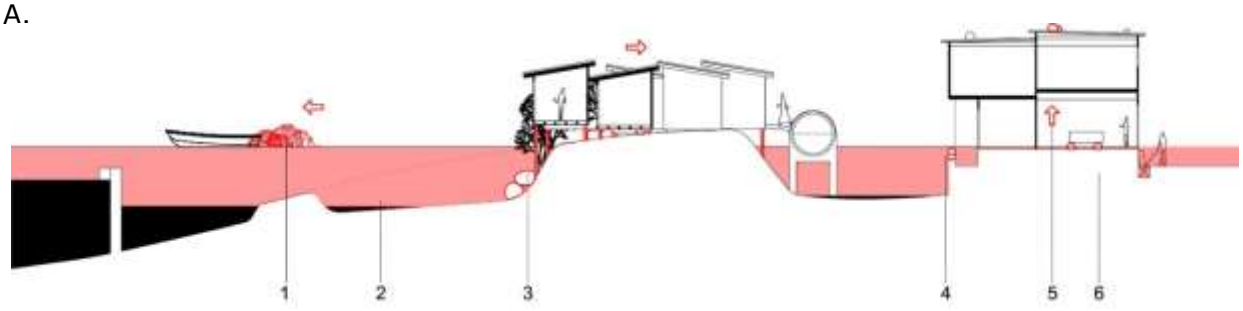
| | | | | | |
|---|---|---|---|---|---|
| | tides, flooding | disposal of used water | Storage of water for dry season | Household Community | ST |
| | | | Creating open water tanks | Community NGOs | LT |
| | | | Water diversion for laundry grounds (Ex. Dhobi Ghat) | Community NGOs | LT |
| Tannery | Flooding in industries | The waste from tannery industries is dumped in waterlines | Relocation to higher levels, use of plastics on roof/ windows | Household | ST |
| | | | Construction of barriers | Household | ST |
| | | | Dewatering pumps to drain floodwater | Household Community | ST |
| Recycling | Flooding | | Raising of plinths | Household | ST |
| | Water pollution | | Cleaning the water channels | Community Government NGOs | LT |
| *Papadwalas* | Flooding in public space used for drying papads | | Relocation | Household | ST |
| Dying Industries | Water pollution | The waste water from the dying industries is fed into the water channels | Storage of water for dry season | Community | LT |
| | Scarcity of water | | | | |
| Street vendors | Flooding | | Relocation | Household | ST |
| Household activities | Inadequate drinking supplies | The water from excess rain is collected for washing clothes, bathing etc. | Community collection points | Community NGOs | LT |
| | Flooding | | Plastic sheet to cover windows and over the roofs. | Household | ST |
| | | | Temporary relocation to upper floors in individual dwelling | Household | ST |
| Shopkeepers | Flooding | | Raising furniture, covering with plastic, canopy projections etc. | Household | ST |
| | | | Temporary relocation to upper floors in individual shops | Household | ST |
| | | | Dewatering pumps to drain floodwater | Community NGOs | ST |
| | | | Cleaning of community drains | Community Government NGOs | LT |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Rural** | Shortage of water | Agriculture | Water scarcity Soil erosion | Increase food variety and decrease food insecurity; commercial food | Diversification of crops and drought-tolerant crops (e.g., sorghum, cassava, millet) | Household | LT | Thierfelder et al. 2015 |
| | | | | Fertile soils near rivers which increases food productivity | Crops at river basin to increase irrigation | Household | ST | Albuquerque & Hobbs 2016 |
| | | | | New opportunities of income and shift to more resilient livelihoods | Livelihood diversification (e.g., livestock herding, small business, mining, tourism) | Household Community | LT | Costa et al., 2016; Osbahr et al., 2008 |
| | | | | Increase of cooperation and social cohesion | Social networks to disseminate information on successful management practices | Household Community | LT | Albizuaet al., 2021 |
| | | | Increase of pests | Increase cash income by trading forest products | Reliance on forest resources | Household | ST | Angelsen & Wunder, 2003 |
| | | | HWC | | Guarding crop fields and HWC mitigation | Household | ST | MITADER, 2008 |
| | | | Low productivity | Increase of community empowerment | Community-based management & fishing rotation areas | Community Government NGOs | LT | Costa et al., 2016 |
| | | Fishery (Kimwani) | Increase of invasive species | New opportunities of income and shift to more resilient livelihoods | Aquaculture | Community Government NGOs | ST | MICOA 2012 |
| | | | | | Livelihood diversification | Household | LT | WFP 2021 |
| | | | Mangrove destruction | Increase of community empowerment | Rotation systems for mangrove logging and fishing | Government NGOs | LT | WFP 2021 |
| | | Forestry | Increase the risk of wildfires | Change land management practices (e.g., slash and burn) | Community-based management | Government NGOs | LT | WFP 2021; Cochrane, 2009; Bare et al., 2010 |
| | | | Loss of timber and non-timber species | | | Household | ST | |
| | | Hunting (Makonde) | Species migration, increase of zoonotic diseases, HWC | | Reliance on forest resources | Household | ST | Roseiro 2013 |
| | Flooding | Household activities | Overheating | Sustainable and nature-based materials | House infrastructure and material (adobe and dry grass roofs) | Community | LT | Costa et al., 2016 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Water quality | Natural hazards | Increase of cooperation and social cohesion | Strong social networks to share knowledge a bout weather forecast and climate information; cooperation and collective action | Community | LT | WFP 2021 |
| | | | | Construction of dams | Government NGOs | LT | Artur & Hilhorst, 2012 |
| | Sea level rise | Shortage and lack of quality water | | Rainwater harvesting (e.g. by digging the stem of large trees, or by collecting rain from the roofs) | Household | ST | Costa et al. 2016 |
| | | | | Underwater collection through pond and wells | Community Government NGOs | ST | |
| | | Sea level rise | Reservoir for restocking marine and coastal species for community survival | Relocation | Community | LT | Mucova et al. 2021 |
| | | | | Planting trees as natural barrier | Government NGOs | ST | |

Figura 4. Water-induced risks and strategies for marginal communities in urban and rural settings derived from the two case-studies (Authors). LT: Long term; ST: Short term
Fuente: Elaboración propia

A.

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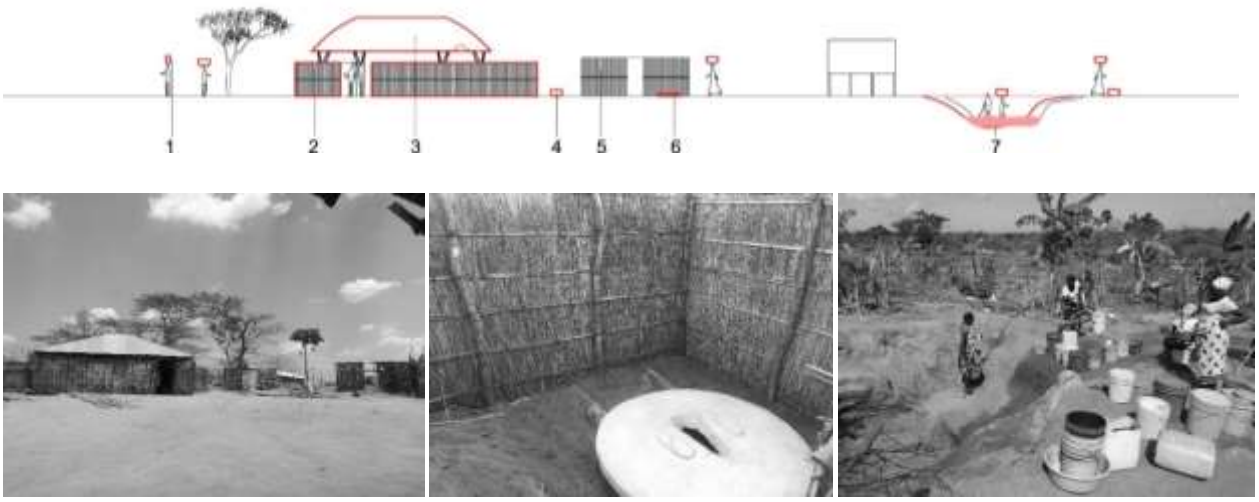


Figura 5. Cross-sections derived from the assessed cases illustrating adaptation strategies (in red) to address water-induced risks. Top; A: Mumbai (urban territory of assessment); Bottom; B: Northern Mozambique (rural territory of assessment).
Fuente: Elaboración propia

A: The cross-section derived from Dharavi in Mumbai presents fishermen community along the sea and water channels. The community adapts to water vagaries by building the dwelling units on stilts (marked in 3). Mangroves provide for barriers to tidal surge (marked in 1). Retention ponds (marked in 2) provide for livelihood diversification in developing aquaculture and fish farms. Further, the dwelling units in Dharavi presents industries or the workplace at the lower floor with livable space on the upper floors. Building barriers, raising the furniture and relocation to upper floors (marked in 4, 5 and 6) are observed in the slum. The same are presented in images from Dharavi.

B: The cross-section derived from Northern Mozambique presents the case from rural territory; with water scarcity as a major risk. Risk reduction strategies include community based management with strong social networks, underground collection through ponds (marked in 7, 1 and 4), and household toilets (marked in 5 and 6). Dwelling units are made of adobe bricks and dry grass (marked in 2 and 3) in close relation to climate and site.

# 5 CONCLUSIONS

The vernacular livelihood strategies provide risk reduction by enhancing the adaptive capacity, reducing the exposure and sensitivity towards the vagaries of water in both rural and urban territories. The establishment of vernacular adaptation strategies in water-induced risk reduction for the marginal vulnerable groups in the light of the limited formal government assistance has a significant role. The urban form and built elements within the marginal settlements is the result of the decisions and constant attempt to overcome the vulnerability factors and water-risk drivers that prevail from the site and climate change. The exposure and sensitivity towards the vagaries of water is progressively being seen as an opportunity to learn how to enhance the adaptive capacity to live in harmony with water. Further, the description of such strategies in two different types of marginal communities – rural and urban – bring to light inherit differences in local water-risk adaptation strategies. In rural areas,

most of the applied strategies are to overcome the impacts of water scarcity in agriculture production – the main food source – and livelihood strategies are yet very nature-based and less dependent on external services or products. However, climate change and the increase of water-risks are compromising communities' capacity to be self-sustainable, and will worsen in the near future. On the other hand, in urban areas, marginal communities have adapted to use plastic and other resistant waste from urban centers and focus their strategies on infrastructure adaptation to protect against sea level rise. The closeness to city hubs enables them to use urban materials for water-risks adaptation and offers increased opportunities for livelihood diversification. However, it also makes communities more dependent on external aid and susceptible to social-political changes (Xu & Takahashi 2021). Therefore, the knowledge about the strategies of adaptation that are currently in place in these two settings might provide solutions to future decisions towards addressing water induced risks for marginal groups, but also to manage the susceptibility of such strategies to near future climate changes. Results provide holistic findings that contribute to the lexicon of water-risk adaptation for marginal settlements in developing countries and can be used to design and render future marginal settlements water risk resilient with vernacular approach involving community participation, rather than merely depending upon external formal measures. Thus, the risk paradigm should shift from institutional top-down to more integrated approaches with local participation and community led vernacular measures with the involvement of those at risk. The illustration of identified adaptation measures in different territories through cross-sectional drawings provide for the initial grounding of preparing the lexicon or a handbook, for rendering future marginal settlements risk resilient.

## 6 AUTHOR CONTRIBUTIONS

Both the authors conceived of the presented idea. First author developed the theory, wrote the manuscript with support from the second author. Both the authors provided critical feedback, discussed the results and contributed to the final manuscript.

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## 8 BIBLIOGRAPHY

Adger, W., Arnell, N., Tompkins, E. (2006). Successful adaptation to climate change across scales. *Global Environmental Change* 15, 77–86. doi: 10.1016/j.gloenvcha.2004.12.005

Anderson JL, Pariela F (2005) *Strategies to mitigate human-wildlife conflicts Mozambique (Report).* FAO, Rome.

Angelsen, A., Wunder, S. (2003). *Exploring the Forest – Poverty Link: Key concepts,Issues and Research Implications (report).* CIFOR Occasional Paper, 40, Indonesia. doi:10.17528/cifor/001211

Angoua ELE., Dongo K, Templeton MR, Zinsstag J, Bonfoh B (2018). Barriers to access improved water and sanitation in poor peri-urban settlements of Abidjan, Côte d'Ivoire. *PLoS ONE* 13(8):1–13. doi:10.1371/journal.pone.0202928

Albizua A, Bennett EM, Larocque G, Krause RW, Pascual U (2021) Social networks influence farming practices and agrarian sustainability. *Plos One* 16(1): e0244619. doi:10.1371/journal.pone.0244619

Albuquerque, A. De, Hobbs, A., & Hobbs, A. (2016). *Challenges and Opportunities for Efficient Land Use in Mozambique : Taxes , Financing , and Infrastructure (report).* Climate Policy Initiative.

Artur, L., & Hilhorst, D. (2012). Everyday realities of climate change adaptation in Mozambique. *Global Environmental Change*, 22(2), 529–536. doi:10.1016/j.gloenvcha.2011.11.013

Asefi-Najafabady, S., Vandecar, K. L., Seimon, A., Lawrence, P., & Lawrence, D. (2018). Climate change, population, and poverty: vulnerability and exposure to heat stress in countries bordering the Great Lakes of Africa. *Climatic Change*, 148(4), 561–573. doi:10.1007/s10584-018-2211-5

Baird, Tiimothy; Gray, C. (2014). Livelihood Diversification and Shifting Social Networks of Exchange: A Social Network Transition?. *World Development*, 60, 14-30. doi:10.1016/j.worlddev.2014.02.002.

Bare, M., Kauffman, C., Miller, D. C., Hosonuma, N., Herold, M., Sy, V. De, Wells, J. A., Wilson, K. A., Abram, N. K., Hermans-neumann, K., Gerstner, K., Geijzendorffer, I. R., & Herold, M. (2010). *Why do forest products become less available ? A pan-tropical comparison of drivers of forest-resource degradation*.doi: 10.1088/1748-9326/11/12/125010

Brouwer, R, Mabunda, R (2005). *Livelihoods: An Analysis and Proposal to Reconcile Conservation and Development in the Buffer Zone of the Quirimbas National* (report),WWF Mozambique, Maputo.

Ceauşu S, Graves RA, Killion AK, Svenning JC, Carter NH (2019) Governing trade-offs in ecosystem services and disservices to achieve human–wildlife coexistence. *Conservation Biology* 33(3):543–553. doi:10.1111/cobi.13241

Chambers R., Conway ,G. (1992) Sustainable rural livelihoods: practical concepts for the 21st century. *IDS Discussion Paper* 296(29). doi: ISBN 0 903715 58 9

Charles, A. (ed.) (2021). Communities, conservation and livelihoods. Gland, Switzerland: IUCN and Halifax, Canada: Community Conservation Research Network. doi:10.2305/IUCN.CH.2021.01.en

Chatterjee, Monalisa. (2010). Resilient Flood Loss Response Systems for Vulnerable Populations in Mumbai: A Neglected Alternative, The State University of New Jersey. dOI:10.7282/T3G44Q2X

Cochrane, M.A. (2009). Tropical Fire ecology, Climate change, Land use, and Ecosystem Dynamics. Springer, Chichester, UK. dOI:10.5860/choice.47-1397

Costa, H., Paula, A., Álvaro, C., Rubens, J., Augusto, L., Fernando, J.C., Omar, R. & Paula, J. (2016). Climate Vulnerability Assessment and Adaptation Priorities for the Quirimbas National Park (QNP). Final report. Biodinâmica S.A. prepared to WWF – MCO. Pemba, Mozambique, 145pp.

Dharavi weekly. (2020). Water city, Water everywhere - but not when you need it, Urbz. http://urbz.net

Dickson, S. E., Schuster-Wallace, C. J., & Newton, J. J. (2016). Water Security Assessment Indicators: The Rural Context. *Water Resources Management,* 30(5), 1567–1604. doi:10.1007/s11269-016-1254-5

Dunham KM, Ghiurghi A, Cumbi R, Urbano F (2010). Human-wildlife conflict in Mozambique: A national perspective, with emphasis on wildlife attacks on humans. *Oryx* 44(2):185–193. doi: 10.1017/S003060530999086X

Eakin H., Luers A.L. (2006) Assessing the vulnerability of social- environmental systems. *Annual Review Environmental Resources*, 31, 365–394. doi:10.1146/annurev.energy.30.050504.144352

Faurès, J.-M., & Santini, G. (2009). *Water and the Rural Poor Interventions for improving livelihoods in sub-Saharan Africa (report).* FAO Land and Water division, Rome.

Garrick, D., Hall, J.W. (2014). Water security and society: Risks, Metrics and Pathways. *Annual Review Environmental Resources*, 39, 611-639. doi:10.1146/annurev-environ-013012-093817

Grasham, C. F., Korzenevica, M., Charles, K. J. (2019). On considering climate resilience in urban water security: A review of the vulnerability of the urban poor in sub-Saharan Africa. In *WIREs Water*, 6(3). doi:10.1002/wat2.1344

Goyal, A. (2021). ESTRATEGIAS Y ENFOQUES PERTINENTES AL ESPACIO PÚBLICO PARA HACER FRENTE A LAS INUNDACIONES. A: "Seminario Internacional de Investigación en Urbanismo", Universitat Politècnica de Catalunya, Grup de Recerca en Urbanisme, Universitat Politècnica de Catalunya, Barcelona, 13. doi:10.5821/siiu.10153

Gujral L, Sema C, Rebaudet S, et al. (2013). Cholera epidemiology in Mozambique using national surveillance data. *J Infect Dis*, 208(1),107–14. dOI:10.1093/infdis/jit212

Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change-A case study in Mozambique. *Global Environmental Change*, 19(1), 74–88. doi:10.1016/j.gloenvcha.2008.11.002

INE (2017). *4° Censo Geral da População e Habitação 2017*. Instituto Nacional de Estatística de Moçambique (www.ine.co.mz)

IPCC (2001).Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report. Cambridge University Press, Cambridge, UK. doi:10.1002/joc.775

IPCC (2007). Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2018) Global Warming of 1.5°C Special Report. Cambridge University Press, Cambridge, UK.

Lamichhane, B.R., Persoon, G.A., Leirs, H., Poudel, S., Subedi, N., Pokheral, C.P., Bhattarai, S., Thapaliya, B.P., et al. (2018) Spatio-temporal patterns of attacks on human and economic losses from wildlife in Chitwan National Park, Nepal. *PLoS ONE* 13(4):1–18. doi:10.1371/journal.pone.0195373

MICOA (2012). Perfil Ambiental e mapeamento do uso actual da terra nos distritos da zona costeira de Moçambique (report). Impacto, projectos e estudos ambientais, Cabo Delgado.

MITADER (2012) *Plano de Maneio 2011-2021 Parque Nacional das Quirimbas*. Ministry of Tourism, Pemba, Mozambique

Mucova, S.A.R., Filho, W.L., Azeiteiro, U.M., Pereira, M.J. (2018) Assessment of land use and land cover changes from 1979 to 2017 and biodiversity & land management approach in Quirimbas National Park, Northern Mozambique, Africa. *Global Ecology and Conservation*, 16. doi:10.1016/j.gecco.2018.e00447

Mugabe, V. A., Gudo, E. S., Inlamea, O. F., Kitron, U., & Ribeiro, G. S. (2021). Natural disasters, population displacement and health emergencies: Multiple public health threats in Mozambique. *BMJ Global Health*, 6(9). doi:10.1136/bmjgh-2021-006778

Orr, S., Cartwright, A., Tickner, D. (2009). WWF water security series 4: understanding water risks, a primer on the consequences of water scarcity for government and business (report).

Osbahr, H., Twyman, C., Adger, W., Thomas, D., (2008). Effective livelihoods adaptation to climate change disturbance: scale dimensions of practice in Mozambique. *Geoforum* 39, 1951–1964. doi: 10.1016/j.geoforum.2008.07.010

Pereira, J.; Rosalino, L.M., Mucova, S., Massangue, Y., Abdulrazark, M., Vahossa, S., Selemane, M., Fonseca, C., Santos, M.J. (2021). Livelihood vulnerability increases human-wildlife interactions. *Environmental Conservation*. 1-9 pp. doi:10.1017/S037689292100028X

Pereira, J., Santos, M.J., Rosalino, L.M. (2022). Role of local communities in the social network of the protected area management. Conservation Science and Practice, e12664. doi:10.1111/csp2.12664

Ratnayeke, S., Van Manen, F.T., Pieris, R., Pragash, V.S.J. (2014) Challenges of Large Carnivore Conservation : Sloth Bear Attacks in Sri Lanka. *Human Ecology* (42):467-479. doi:10.1007/s10745-014-9643-y

Roseiro, A.H.R. (2013). Símbolos e práticas culturais dos Makonde (thesis). Coimbra University, Portugal. URI:hdl.handle.net/10316/23804

Rrokaj, S., Corti, B., Giovannini, A., Cancelliere, G., Biotto, D., Radice, A. (2021). Flood mitigation measure and water storage in east africa: An analysis for the rio muaguide, Mozambique. In *Hydrology*, 8(2). doi:10.3390/hydrology8020092

Smits, J. (2016). GDL Area Database. Sub-national development indicators for research and policy-making. *GDL Working paper* 16-101

Thiault, L., Jupiter, S. D., Johnson, J. E., Cinner, J. E., Jarvis, R. M., Heron, S. F., Maina, J. M., Marshall, N. A., Marshall, P. A., & Claudet, J. (2021). Harnessing the potential of vulnerability assessments for managing social-ecological systems. *Ecology and Society*, 26(2). doi:10.5751/ES-12167-260201

Thierfelder, C., Rusinamhodzi, L., Setimela, P., Walker, F., & Eash, N. (2016). Conservation agriculture and drought-tolerant germplasm: Reaping the benefits of climate-smart agriculture technologies in central Mozambique. *Renewable Agriculture and Food Systems*, 31(5), 414-428. doi:10.1017/S1742170515000332

Treves A (2009) Hunting for large carnivore conservation. *Journal of Applied Ecology* 46:1350–1356. doi:10.1111/j.1365-2664.2009.01729.x

WFP (2021). *Food security and livelihoods under a changing climate in Mozambique: Preparing for the future (report*). Rome, Italy.

World Economic Forum. (2016). *The Global Risks Report 2016: Insight Report, 11th Edition*. Geneva: The World Economic Forum.

Xu, J.; Takahashi, M. Urban Marginalization and the Declining Capacity for Disaster Risks in Contemporary China. *Soc. Sci.* 2021, *10*, 424. doi:10.3390/socsci10110424