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River basin flood adaptation for coastal urban slums. Mithi river basin, Dharavi slum

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Abstract

Urban slums in developing countries host a substantial proportion of the urban population. Slums are located on land usually unsuitable for formal development, along the river basins or coastal mangroves that makes them at a greater risk of flooding. River basins face a continuous conflict between mushrooming slums and environmental needs being most vulnerable to changing water levels, plays a significant landscape infrastructure in building flood resilience and provides for spatial interplay between floods and measures of adaptation. The paper investigates how this physical space can be turned into an adaptive interplay to address floods in coastal slums. The methodology involves observation and interpretation from reality. Dharavi slum is assessed to develop a landscape typological framework of flood adaptation set in the parameters based on the functions in different zones that demonstrates the role of river basins towards the integrated approach for flood adaptation in urban slums.

Gli slum urbani nei paesi in via di sviluppo ospitano una parte considerevole della popolazione urbana. Generalmente si trovano su terreni inadatti allo sviluppo formale, lungo i bacini fluviali o le mangrovie costiere che li rendono a maggior rischio di inondazioni. Caratterizzati per il conflitto continuo tra gli slum in crescita e le esigenze ambientali, consistono in una significativa infrastruttura paesaggistica nella costruzione della resilienza alle inondazioni, dove se possono leggere parsimoniose misure de adattamento. L'articolo indaga su come questo spazio può diventare un'interazione adattiva per affrontare le inondazioni negli slum costieri. L'osservazione e l'interpretazione dalla realtà consentono di sviluppare un quadro tipologico di adattamento del paesaggio dello slum di Dharavi, impostato nei parametri basati sulle funzioni nelle diverse zone, che dimostra il ruolo dei bacini fluviali verso l'approccio integrato per l'adattamento alle inondazioni negli slum urbani.

Keywords

Flood adaptation, Flood control basin, River basin, Urban slum.

Adattamento alle inondazioni, Bacino di controllo delle inondazioni, Bacino fluviale, Slum urbani.

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Introduction

Slums are informal neighbourhoods characterized by overcrowding and poor infra-structure. "[…] a contiguous settlement where the inhabitants are characterized as having inadequate housing and basic services. A slum is often not recognized and addressed by the public authorities as an integral or equal part of the city" (UN Habitat, 2003, p. 8). In developing countries of global south, urban slums host a large proportion of population. Here, 'global south' is simplistically referred to in the terms of geography, to consolidate the group of countries facing disadvantages on the basis of economic system, the Brandt line, as a way of geographically classifying the countries into relatively richer and poorer nations. "The Global south is not an entity that exists *per se* but has to be understood as something that is created, imagined, invented, maintained, and recreated by the ever-changing and never fixed status positions of social actors and institutions" (Kloß, 2017).

Globally, in 2018, 23.5 percent of urban population lived in slums. The absolute number of people living in slums grew to over 1 billion, with 80 percent attributed to three regions: Eastern and South–Eastern Asia (370 million), Sub–Saharan Africa (238 million) and Central and Southern Asia (227 million) (UN Habitat, 2019).

> "The explosive growth of the slums in the last decades, from Mexico city and other Latin American capitals through Africa to India, China, the Philippines and Indonesia, is perhaps the crucial geopolitical event of our times […] We are witnessing the rapid growth of a population outside the control of any state, mostly outside the law, in terrible need of minimal forms of self-organization" (Žižek, 2004).

At national level, according to the Census of India in 2011, nearly 17 percent of urban population i.e. more than 65 million people lived in slums (Census of India, 2011). In Mumbai, which hosts Dharavi slum along the Mithi River, nearly 54 percent of urban population lives in slums (Census of India, 2001).

Mostly, the slums occupy land unsuitable for formal development. Therefore, the low lying marshy areas along the river basins or coastal mangroves near large cities are particularly pressured by this form of occupation. As a direct cause, the physical location makes them at a greater risk of flooding. A particular flood can result from many combinations of meteorological, hydrological and human factors (Matos Silva, 2016, p. 81). It is realized that coastal urban slums are more vulnerable towards risks induced by climate change and sea level rise. Flooding is not just related with heavy rains or extreme climatic events but is also related with the ability of the built area of an urban slum to absorb the excess water or prevent the overflowing of water. "Uncontrolled ur-

Fig. 1 – Location of Mithi River, Dharavi slum in Mumbai. (Elaboration by Author).

banization has rapidly consumed rural land and systematically encroached on water bodies, floodplains and wetlands, resulting in a fragmented ecosystem" (Claudia Rojas et al., 2015, p. 177). Due to absence of adequate formal flood adaptation measures, infrastructure and basic services urban slums lack the ability to prevent or absorb excess water. The dwellers are imposed with the impact of recurring floods from extreme climate events such as cyclones, tidal surges etc. According to IPCC, there is high confidence that "Coastal systems and low-lying areas will increasingly experience submergence, flooding and erosion throughout the 21st century and beyond, due to sea level rise" (Pachauri et al., 2014, p. 74). Also is predicted by 2100, about 70 percent of the coastline worldwide are projected to experience sea level change within 20 percent of the global mean. In this sense, it is essential, to investigate and avail the ability of adaptive public space such as river basin that exist with the coastal urban slums in addressing the floods.

A river is a process that is governed by changing water levels, shifting seasons, erosion and sedimentation. "It creates land and water from ubiquitous wetness, defining them on either side of a line. It is one of the first acts of design, setting out a ground of habitation with a line that has largely been naturalized in features such as the coastline, the riverbank, and the water's edge" (da Cunha, 2019). The river environment is not static rather a dynamic process. River basins, inscribed in a geographical area, face a continuous conflict between the mushrooming slums and the environmental needs. We can consider that in river basins there exists a spatial interplay between the floods and the measures of adaptation and mitigation. Restoration and conservation of coastal and riparian ecosystems as alternatives to infrastructural measures are increasingly being explored (Barbier et al., 2011) (Borsje et al., 2011). A constant adaptation subsists in coastal slums in close relation with water. River basin is "the entire geographical area drained by a river and its tributaries" (Sanghani, 2009, p. 3). It plays as a significant landscape infrastructure towards building blood resilience for coastal slums.

The objective of the paper is to investigate and examine the research question of how this physical space in wetlands can be turned into an adaptive interplay between the water and adaptation measures by the local slum dwellers to address floods.

The methodology involves observation and interpretation from the case of Mithi River basin, Dharavi slum in Mumbai, India (Fig. 1). The drawings are derived from the spatial assessment of the case, assisting towards the development of a comprehensive systematization, a typological framework of effective measures and innovative design elements that further could be conceptualized into the design of future flood resilient coastal urban slums.

Material

Mithi River, an arterial river, runs 17.84 km along North–South axis of Mumbai. The river originates from the confluence of two essential reservoirs; Vihar Lake and Powai Lake and merges with Arabian Sea at Mahim creek. The flow in the river primarily is due to the over flow of water from the weirs of the Powai and Vihar lakes, excruciated by the intense rainfall during monsoons from June–August (Sanghani, 2009, p. 3). Dharavi slum, with early community of Kolis – the fishing community, originated in early 18th century along the Mithi River. The slum that occupies low lying marshy land, along the Mithi River, hosts a population of about 1 million in an area of 2.1 square kilometers (WEF, 2016). This translates into a very high population density of 270,000 – 450,000 inhabitants per square kilometer (average population density in Mumbai is 29,500 per square kilometer (NOAA, 2011). Mithi River basin face a continuous conflict between this mushrooming slum and its environmental needs. From the original blanket area of 800 ha, some 400 ha was reclaimed and Mithi River was narrowed from its well defined siphon creek to a mere storm water drain (Sanghani, 2009, p. 1). The change in Mithi river basin, between 1976 and 2005, along Dharavi slum is illustrated in figure 2. Thus, over the years, Mithi river basin is facing haphazard development, reclamation and concreting resulting into reduction of percolation surface thereby accelerating the run off. According to Concerned Citizens' Commission: An enquiry into the Mumbai Floods, 2005: Mumbai has lost about 40 percent of the mangroves between 1995 and 2005 (CAT, 2005). Bandra–Kurla Complex, abutting Mithi River, opposite of Dharavi slum, has been created by replacing such swamps and mangrove area. The river basin and ecosystem has lost its existence for the fact that city's very own social interaction and influx has steadily transformed and weakened the endoskeleton of the city (Sanghani, 2009,

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Mithi River boundary in 1976 ■ Mithi River in 2005 □ Dharavi slum

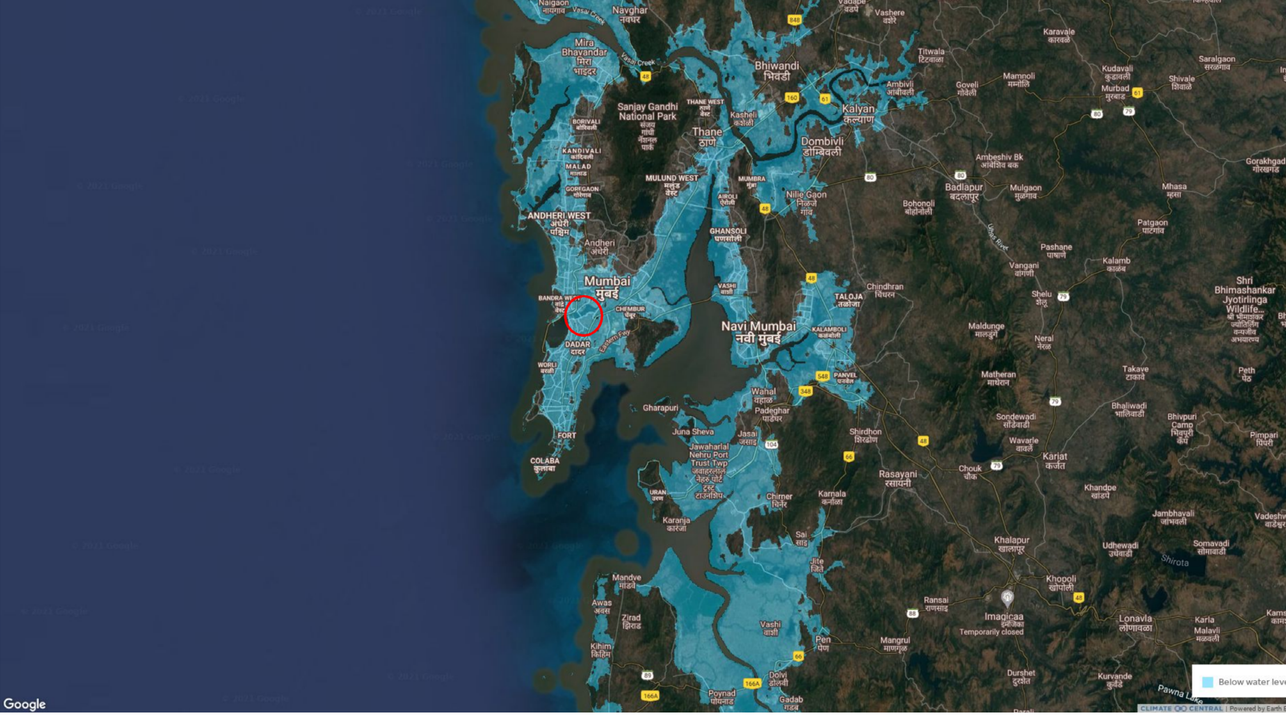
Fig. 2 – The change in Mithi River basin between 1976 and 2005 (Elaboration by Autor, 2021, derived from Survey of India Topographic Sheet, 1976).

p. 4). Mithi River, being Mumbai's natural water system which helps drain off excess water, turned into open sewer drain without the riverbanks. The mushrooming slums along the Mithi River has resulted in a drastic transformation of river system: the encroachment of floodplains, water bodies, wetlands, expansion of impermeable surfaces, depleting mangroves and inadequate waste management being the reasons for the dearth of Mithi River. "When the accumulation of incremental changes exceeds the capacity of the ecosystems to adapt to such changes resilience is lost" (Holling & Goldberg, 1971).

Throughout the making of Dharavi, water had a close relation in shaping its spatial configuration. Over the years, the slum has built upon the tensions of top-down urban strategies and bottom-up tactics of spatial adaptation regarding the capacity to address the risk from flooding. The mushrooming development in the river basin has to be harmonized with the vagaries of water.

Method

Recurrent floods and water presents significant risks given the topography and physical location of coastal Dharavi slum in the city. Recurring extreme rainfall, sea level rise (SLR), with inadequate ability to absorb and prevent in surging water related vulnerabilities, provides high risk to the existence of the



○ Dharavi slum, Mumbai

Fig. 3 – Projected SLR – 2050 Mumbai, India. (Elaboration by Autor, 2021, derived from http://www.climatecentral.org/).

coastal slums. Figure 3 illustrates the SLR for Mumbai in a moderate scenario as proposed by Kopp for the climate central modelling tool. The cities of global south faces the challenge to deal with pressure of mushrooming slums in flood prone areas while simultaneously finding solutions to address floods. It substantiates the need and significance of availing the ability of physical space of river basins that can be turned into an adaptive interplay to address floods in slums located along the rivers. It is manifested, in the absence of formal measures that slum dwellers inherit local flood adaptation and mitigation measures. The excess of water seen as a threat, is progressively changing into being seen as an opportunity. The objective of the paper is to investigate, systematize and develop a comprehensive framework of such measures at river basin level.

The methodology involves observation and interpretation from the case of Mithi River basin, Dharavi slum in Mumbai, India. The drawings are derived from the spatial assessment of the case to gaze and systematize the flood adaptation and mitigation measures and built elements. The measures are graphically categorized in three zones of river basin: aquatic, amphibious and terrestrial zones, assisting towards a comprehensive assessment of measures in close relation with changing water in different zones. Such assessment explores the relations between infrastructural needs of the slum dwellers, landscape and the physical transformation of landscape and infrastructure. The aquatic zone is the part of river basin which is always submerged. This zone is predominantly used by water such as river bed.

Amphibious zone comprises the space of river basin which is used both by water and slum dwellers. This space demonstrates a high level of adaptation and a conflict of shared space. The space used by water during wet months, June–August, is observed to be used by slum dwellers for leisure and cultural activities in dry months. The same space is also used for constructing houses on stilts. Terrestrial zone is the space above an average water stage that encompasses the adjacent riparian land. Further, the measures are set in the parameters based on the functions such as retention, storage and detention of water. The measures that comprises the ability to control the excess flow of water by absorbing the water are categorized as retention. Such infrastructural measures retains a permanent pool of water. Measures that entail the infrastructural capacity to store or hold the water are categorized as storage. These measures can be below or over the ground surface such as a holding pond. The stored water is cleaned and filtered and subsequently used for aquaculture, laundry or bathing purposes by the slum dwellers. Detention based infrastructural measures does not have a permanent pool of water. Such measures supply back the water into river during the dry season. The conversion of the conflicted relations between the urban slum and environmental needs into a constructive interplay, through local adaptation measures that work with the logics of the site and in relation to fragile water realities is essential for building flood resilience. The framework illustrated in table 1 provide for a systematized structure that could assist the process of rendering the future urban slums flood resilient.

Results and discussion

The paper investigates the local flood adaptation and mitigation measures by coastal urban slum, that exist in river basin in fluctuating way in the 'borderlands' between water and land. The result showcase the potential role of river basin along the coastal slums in addressing floods through local effective measures and built elements which are result of continuous adaptation for living in harmony with water.

Climate change related sea level rise and an increase in flood frequency have brought the line of separation into sharp focus leading to proposals for walls, levees, natural defenses, and land retirement plans (da Cunha, 2019). In the coupled system with land and water in synergy, the innovative approaches to site regeneration are dynamic processes, performance and adaptation through time, replacing outmoded emphases on static structures (Lis-

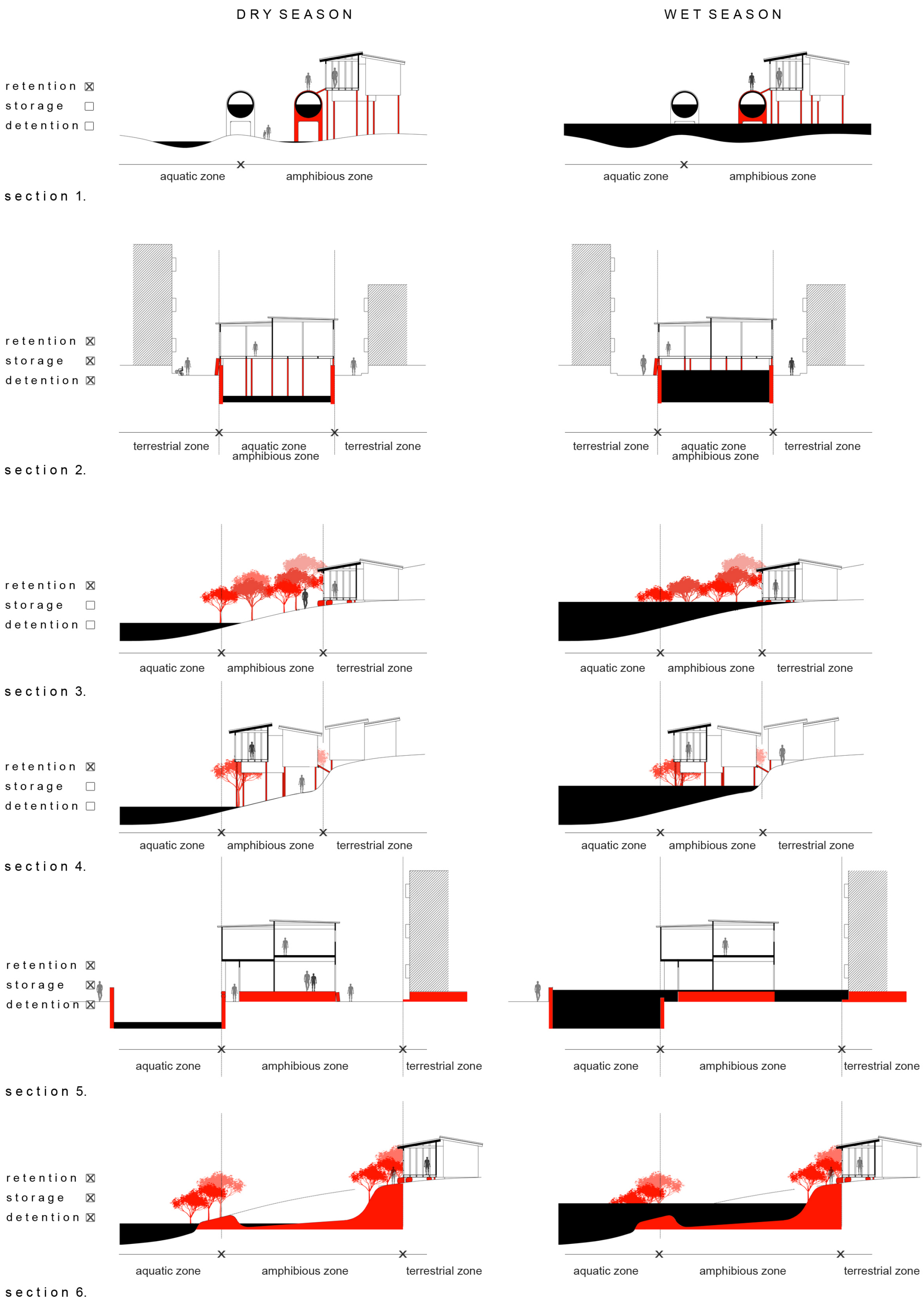


Fig. 4 –Cross-sections derived from Dharavi slum, illustrating the systematization of flood adaptation measures and built elements (Elaboration by Autor,). Red: flood adaptation and mitigation measures and built elements.

River basin level flood adaptation and mitigation measures	Functions		Parameter based on function	Cross-section (Fig. 4)
Mangroves	Adaptation	Sediment trapping Attenuating waves and reducing current velocities. Serves as a first line of defence against flooding and erosion. Stabilizing shorelines	Retention	Sec. 3, 4, 6
	Mitigation	Sequestrating and fixating carbon		
Wetlands	Adaptation	Flood storage, storm surge buffers, erosion control and wildlife habitat.	Retention Storage Detention	Sec. 6
	Mitigation	Reduce pollutant loads from storm events, reduce concentrations of total suspended solids.		
Parks/ Green belts	Adaptation	Flood storage, decreased water runoff, ground water recharge/ discharge, provide for permeable surfaces, physical space for leisure and cultural activities	Retention Storage Detention	Sec. 3, 6
	Mitigation	Fixating carbon		
Ponds/ Tanks	Adaptation	Manage high runoff, provide for storm water retention, infiltration, filtration. Enable livelihood diversification and seasonal farming.	Retention Storage Detention	Sec. 6
	Mitigation	Enhancement of water quality		
Floating greens	Adaptation	Storm surge buffers, provide for livelihood diversification and seasonal farming.	Retention	
	Mitigation	Fixating carbon, wildlife habitat.		
Retention walls	Adaptation	Provide infrastructural ability for retention: protection from change in water levels, storage and detention.	Retention Storage Detention	Sec. 2, 5
Dykes	Adaptation	Provide infrastructural ability for retention: protection from change in water levels, storage and detention.	Retention Storage Detention	Sec. 6
Housing on stilts	Adaptation	Provide infrastructure ability for protection from change in water levels.	Retention	Sec. 1, 2, 4
River bed/ catchment	Adaptation	Permeable surface that provide space for water (in aquatic zone) and human activities (in amphibious zone).	Retention	Sec. 1
	Mitigation	Wildlife habitat, reduce pollutant loads		
Slum streets	Adaptation	Permeable surface that provide for controlled water runoff. Infrastructure that also provide for temporary hold of water.	Detention	Sec. 5
River channels/ drains	Adaptation	Manage high runoff, provide for storm water retention, infiltration, filtration.	Retention Storage Detention	Sec. 2, 5
	Mitigation	Enhancement of water quality		

Table 1: River basin level landscape typological framework of flood adaptation for coastal urban slums. Derived from the case of Mithi River Basin, Dharavi slum (Elaboration by Autor).

ter, 2009). In context of the Mithi River in Mumbai, Mathur and da Cunha (Lister, 2009) in their project *'Soak'* aimed to revitalize the river-land as a synergistic aqueous terrain that address the seasonal rains and the sea level vagaries argued Mumbai to be returned to its natural tendency to soak, rather than to flood, as the only sustainable solution. These arguments and previous researches is of pertinent, taking into the consideration the dimension of these physically vulnerable areas and the population living in these areas, towards the research into the potential role of river basin combined with local effective measures and built elements in addressing floods.

Systematic interpretation derived from the spatial assessment, as illustrated in figure 4, lead to the creation of "the river basin level landscape typological framework of flood adaptation for coastal urban slums", illustrated in table 1. The measures are set in the parameters based on the functions such as retention, storage and detention of water, which also exemplifies towards the possible planning transformative toolkit, a lexicon to address floods.

Conclusions

River basins are highly significant landscape for coastal urban slums. In the absence of adequate formal flood risk adaptation measures which are mostly based on hard engineered measures, the design of urban river basins can provide for multi-dimensional requirements of coastal slums. The assessment of the river basin transformation in the case of Mithi River abutting Dharavi slum demonstrates how water based local interventions were and can be instrumental in addressing the flood risk. This is essential for flood control and building coastal slums flood resilient. The research demonstrates how the physical space in river basin can be harmonically shared both with changing needs of water and abutting coastal slums. The result in the form of a comprehensive typological framework at river basin level that provide for local adaptive measures that could be further conceptualized to enhance the ability to prevent and absorb the floods. These measures constitute different parameters of function, size, approach etc. that can be read and reinterpreted to support a new paradigm to address floods that could re-structure the morphology of coastal urban slums while conceiving water as opportunity.

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Abbreviations

CIAUD, Research Centre for Architecture, Urbanism and Design

UN, United Nations

SLR, Sea level rise