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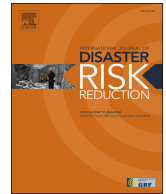
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Political-economic transformation and the reproduction of climate change vulnerability of a high-income city

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ABSTRACT

System transformation is important for low-lying coastal cities to adapt to natural disasters related to climate change, but not all forms of transformation enable adaptation. An important question is how an enduring system change undermines the enabling conditions for reducing vulnerability. This paper addresses the relationship between society-wide transformation and vulnerability reduction. A case study of Macao is used to explain structural vulnerabilities to storm surges in the context of a historic social change process marked by the end of colonial rule. The post-colonial regime seeks political legitimacy from extraordinary economic performance. The capitalist growth model has created new and resilient urban spaces, but reproduced the vulnerabilities of the older ones. The transformation has resulted in a perverse social contract and increased dependence on a shadow regime, undermining the social agency for change. We deconstruct the perceived legitimacy of transformation and examine the social and political consequences of performance legitimization. A society-wide transformation that seeks legitimacy from an unsustainable practice is a recipe for maladaptation. Socio-political realities mediate the effects of transformative social change. Our conclusions highlight the importance of analyzing transformation as an enduring system change. This requires framing the disruptive processes and impacts of transformation as a determinant and explicitly accounting for their socio-temporal dimensions in conceptualizing the non-linear relationship between transformation and vulnerability reduction.

1. Introduction

Transformation of human systems refers to a profound and deep-rooted change to system functioning that challenge existing structures to produce fundamentally novel ones [1–3]. The transformation discourse in climate change scholarship is predicated upon the normative premise that fundamental system change is essential to the transition toward desirable futures [4]. Such a change will address the structural drivers of climate change vulnerability, such as unequal power relationships and poor governance practices that create or preserve a climate-sensitive development pathway [5,6]. In making a case for transformation, there is a tendency among scholarship for taking climate change as a given.

However, system transformation is not commonly driven by climate change alone. Other social, political and economic imperatives often contribute to, if not being responsible for, processes of system transformation that have the scale, depth, and energy to shift development paradigms and trigger an overhaul of entrenched institutions and socio-political relations. System transformation may

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be departed from a climate-resilient pathway, when it is influenced by a range of competing priorities, and climate change is only one of them.

Economic growth is a key policy priority. Many fast-growing Asian cities have experienced various forms of system transformation in the past decades, but whether these transformations have reduced people's vulnerability to climate change and disaster risks remains inconclusive [7–11]. Although transformation changes the system “for the better” [12]; p.352), it does not naturally cohere with the more specific concept of transformative adaptation. There is little empirical investigation into the tensions between these two concepts.

This study draws a conceptual distinction between transformation and transformative adaptation. It explores how a societal transformation determines a city's adaptive capacity by asking ‘*how transformative changes in the wider political, economic and social systems determine the conditions for reducing vulnerability to climate change*’. Transformative adaptation aims to reduce climate change risks. The presence of an adaptation intent makes many existing case studies a poor fit for examining whether a process of system transformation has created better institutional conditions for mitigating these risks. Our study concerns the extent to which a transformative change provides impetus for vulnerability reduction. We therefore focus on a development regime and pathway that are not driven by climate change considerations.

This study examines a planned transfer of governing power, the ensuing shift in development pathway, and their implications for vulnerability reduction. We show how the transforming structures of political economy have created spatial and discursive constraints on an alternative, climate-resilient development pathway. The research responds to the calls for analyzing and practising adaptation as a social change process that entails a transformation of systems and structures [3,13]. It makes conceptual contributions by challenging the idealized relationship between transformation and adaptation, and characterizing the limiting effects of political structures, which are undertheorized [14]. This research provides a realistic account of vulnerability reproduction in the wake of a historic social change process, and insights into the risks and impediments to steering political, economic and social transformations.

The analysis involves a case study of Macao (or Macau). The end of colonial rule marked a drastic transformation of the city's political-economic systems and social structures. Portugal established a permanent settlement in Macao in 1557. In December 1999, the sovereignty of the city was returned to China, which granted the Macao Special Administrative Region (SAR) a unique governance arrangement that enables the SAR to maintain its independent judiciary, legislative and administrative systems. Postcolonial Macao is a prime tourist destination in Asia [15]. Centuries of colonial settlement have left a fine blend of Eurasian cultural legacies and a wealth of exotic Portuguese-style architectures. Today, the city is well known for its lucrative casino tourism, once generating a gaming revenue exceeding that of Las Vegas [16,17].

Macao presents a unique case study for system transformation research, because it was one of the few Western colonies in modern China, its political structures are formally decolonized only recently, and is one of the highest-income economies in the world. Our analysis focuses on the post-colonial changes in Macao, structural vulnerabilities to sea level rise and typhoons, and a fatal urban flooding event in 2017. Despite its uniqueness, the case study can shed light on the contested role of system change in vulnerability reduction in other high-income cities in Asia and beyond.

2. Transformation and climate change vulnerability

2.1. Transformative adaptation

Transformative adaptation is often understood as a desirable outcome of an intentional action. It involves fundamental changes in social systems and structures, and leads to deep changes in broader aspects of development [18]. Such changes would contribute to effective adaptation by addressing the structural drivers of vulnerability to climate change, such as altering established power relations, rebalancing rights and responsibilities, shifting governance or development paradigms, and questioning existing values and assumptions [1,5,6,19–21]. Many scholarly interventions advance the notion of ‘transformation in adaptation’ [18], which involves a deliberate or intentional change in a system for adapting to climate change [1,12,22–24].

Transformation denotes a change for the better [12]. There is a tendency within adaptation scholarship for articulating transformation as a process that will produce positive outcomes for humanity [1,4,21,22]. For example, [23]; p.119) define transformation as a process that results in change in the components of a system, “thereby enhancing the capacity for desired values to be achieved”. The Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report has recognized that “changes to underlying values, worldviews, ideologies, structures, and power relationships” are crucial for human society to adapt to climate change (Schipper et al., 2022, p.2668). The same report suggests that transformative change “could generate benefits to human well-being and planetary health” (Schipper et al., 2022, p. 2658).

Furthermore, transformation is articulated as an intentional, deliberate or directed action [3,22,24,25]. [5] embraces the notion of ‘adaptation as transformation’, which envisions adapting to climate change as a mechanism for transformational change [18]. focus on ‘transformation in adaptation’ and understand transformation as a specific form of adaptation, whereas [20] suggest ‘adaptation through transformation’ and consider system transformation as a means to an end [26]. ‘transformation is adaptation’ is clearly an attempt to interpret one as the other. Therefore, the notion of transformative adaptation implies a good transformation, a targeted and idealized form of system change.

2.2. Contested transformation

However, transformation is essentially a contested process. Critical adaptation scholars understand vulnerability accumulation and reduction as political processes [13,27], but their critiques of the socio-politics of transformation are obscure. [13]; p.12) suggest that interventions aimed at transformation are maladaptive if they are stuck within the same development paradigm that produces

vulnerability. However, vulnerabilities can accumulate under new paradigms. Critiques, debates, and evidence as to whether transformations are responsible for new vulnerabilities remain inadequate.

The history of societal transformation shows that departure from the original – typically good – intentions is common [28]. The process of transformative change can be messy, fraught, and contested [4], risky [5], and inevitably encounters the politics of opposition, division, and othering [24]. Critical adaptation scholars argue that the fundamental shifts in paradigm would involve a negotiation and contestation of values, assumptions, goals, knowledges, and norms ([3,13]. In such a politically and socially contentious process, various interests and actors compete with each other and shape the agenda. The outcomes would not be bound to enhancing adaptive capacity, even if the process is intended to be inclusive [29], empowering [30], and sustainable [9].

There are few successful examples of transformative adaptation [14,22]. Most adaptation initiatives result in an incremental change. There is a lack of interest, mandate, or capacity for tackling inequitable power relations that limit people's access to resources and their agency for change in the first place, resulting in the reproduction, redistribution or creation of vulnerabilities [13]. Some adaptation actions are described as transformative, but most of the case studies are based on strategic, discrete interventions within a community or sector [21,31–33]. The transformative events reported are limited to the specific actors involved and the processes of these planned interventions, rather than the society at large across cycles of development. It is not clear whether the transformation involved is episodic or structural, short-lived or enduring, and about a particular process or the entire system.

Breadth and desirability are different attributes of a system change. An enduring change in a system, such as decolonization and migration, may consist of a bundle or series of interventions and events that occur in a long timeframe and collectively constitute a shift toward a qualitatively different state. Such interventions and events include those that could contest existing norms, knowledge systems, governance structures, and development pathways that produce vulnerability and pose barriers to adapting to climate change. Although the wider social change that leads to these interventions and events constitutes a transformation, the adaptation action may be incremental, ineffective and counterproductive.

Fundamental change in system functioning could be maladaptive, mitigating some risks while producing unintended consequences and uncertainties [5,34]. If transformation is indeed 'messier' than incremental change, more of these consequences and uncertainties might occur. The tensions are evident in many Global South case studies.

2.3. Mixed impacts of system change on vulnerability

Major shifts in development pathways create both positive and negative impacts on people's socio-economic vulnerabilities. Tensions often arise from fundamental changes in models or patterns of economic and institutional development. For example, economic stresses and marginalization contribute to climate change vulnerability in the Global South. Vietnam has experienced a state-wide transition from central planning to a market economy since the 1980s. This resulted in rising incomes for households and communities and enhanced their economic capacity for coping with coastal hazards. Institutional decentralization in this Southeast Asian country also raised prospects for vulnerability reduction by re-introducing informal social coping mechanisms [7]. In Indonesia's Semarang, regional-level decentralization has altered governance relationships between agencies and improved bottom-up integrated metropolitan planning, which helps address climate change risks [8].

However, the same process of system change can reinforce other sources of vulnerability. In Vietnam, the processes of market liberalization and decentralization have increased the concentration of resources and income inequality, and resulted in the decline of formal communal institutions and collective action pivotal to coping with coastal hazards [7]. Decentralization of institutions without devolving power is also a recipe for poor response to flooding, as a case study of Bangkok has shown [10].

Tourism development that shifts development pathway can be transformative. However, the ensuing changes often have different implications for adaptation, such as increasing job security and local finance, while undermining the social conditions for reducing vulnerability. In the Mexican Caribbean, decades of coastal mass tourism have allowed a coalition of government and tourism corporations to accumulate capital and power. This has provided support to some adaptation practices, such as increasing coastal vegetation and insurance coverage, but has weakened the oppositional civil society and reduced the diversity of development visions, which could help the Mexican cities build social capacity for adapting to climate change impacts, notably hurricanes [35]. Similarly, a coastal town of China has attracted resources for adapting to sea level rise, capitalizing on a transformative tourism intervention [9,36]. The revitalized development pathway has maladaptive elements, such as a gradual decline in social capital and the increasing opportunity cost of climate-resilient land use. Existing vulnerabilities are reduced at the expense of other ones.

Clearly, not all forms of transformation create enabling conditions for climate change vulnerability reduction. The key issue is what mechanisms undermine these conditions. Conceptualizing such mechanisms requires a move away from the framing of transformation as a (desirable) outcome. The risks and unintended consequences of disruptive transformation warrant theoretical recognition.

2.4. Adaptation and performance legitimization

We use the Adaptive Cycle heuristic to help analyze how system transformation shapes a city's adaptive capacity. Advanced by Ref. [37]; this heuristic describes the dynamic process in which climate change impacts are understood and experienced, institutions and organizations respond to these impacts, and adaptation interventions occur. There are four phases in the adaptive cycle, namely, institutionalized, scattered, mobilized, and polarized. The state of social systems in this process is understood in terms of the agency of social capital and the structure of the society, which primarily involve action and behaviour, and discourse and institutions, respectively (Table 1). This heuristic is used in this paper for unpacking the decade-long transformation process in Macao, highlighting the power dynamics, and explaining how this process impeded a transition in the adaptive cycle.

Table 1
The four phases of the adaptive cycle.

Adaptive cycle phase	Agency of social capital (action and behavior)	Social structure (discourse and institutions)
Institutionalized	Agency reinforces and is aligned to dominant social structures and institutions. Alternative behavior is marginalized or excluded.	Cohesive structure legitimates prevalent social behavior. Alternative discourses and associated institutions are marginalized or excluded.
Scattered	Diffuse and diverse, social capital and behavior can break away from normalized routines and positions. A space for alternatives to emerge or be formed	Established institutions and discourse seen to have failed in providing security or explaining risk. While these structures are still in place they are no longer reinforced by social agency initiating a crisis in structural reproduction
Mobilized	Social capital hardens around discrete value positions and specific coalitions of interest emerge.	Contradictory and supportive discourses and institutions coexist in overlapping emergent regimes.
Polarized	Competition between alternative social groups is overt. New hierarchies or non-hierarchies arise.	Fewer, but more forcefully argued differences

Source [37]:

Our research identifies a mechanism that undermines the conditions for adaptation. As [4] have indicated, the transformation discourse has failed to recognize the political processes underpinning transformation. One example is the power-laden process of system change legitimization [38]. understand legitimization as a means to a desirable end by suggesting “how to expand legitimacy for deep radical intervention” in climate-impacted systems as an analytical challenge to overcome. Such a normative conception fails to question who legitimizes a system transformation that inevitably creates risks. Few studies have examined the social and political consequences of legitimization.

We argue that a transforming system, primarily addressing climate change or not, constantly seeks legitimacy from its constituents who share the risks of deliberate radical change. Critical adaptation studies should account for the tension between legitimization and vulnerability reduction within the transforming system. The notion of performance legitimacy [39] is useful for reflecting on the normative framings of transformation in adaptation research.

Properly describing China, the notion of performance legitimacy refers to a practice of government that attempts to gain political mandate and legitimize its rule by accomplishing practical goals, such as economic growth and social stability, rather than by institutionalizing popular elections or liberal-democratic norms [39]. This constitutes a new social contract, which refers to an implicit or explicit agreement among individuals in a society to cooperate for mutual benefits and establish a functioning community. Performance legitimization is successful in China, where the public, especially the urban rich, has accumulated massive wealth from the extraordinary economic growth since 1990s and has developed tolerance to the drawbacks of the regime's authoritarian rule. People's political rights and agency are circumscribed to empower and enable the state to concentrate on economic growth and deliver material benefits and stability. Performance legitimization can be seen as a means by which the state manages the expectations of its citizens who are affected by a deliberate transformation process that reconfigures power relations and reinforces the state's authoritarian control.

Macao is increasingly influenced by China's governance traditions and has achieved impressive macro-economic performance. Our research, described below, suggests that the politics of performance legitimization has shaped the context for climate change adaptation in Macao by influencing the agency of actors and social structures.

3. Study area

Macao is a high-income economy, with an outstanding GDP per capita (current prices) of US\$86,197 in2019.¹ The coastal city sits on a tiny area of 32.9 km² and has a population of 682,070 in 2020 [40]; 2022a). It comprises Macao Peninsula, Taipa, and Coloane. Macao Peninsula, the historical urban centre, is home to the majority of Macao population (532,858, or 78 %) and has an extraordinarily high population density of 57,297 persons/km² [41] (Fig. 1). Between Taipa and Coloane is a 6 km² of newly reclaimed land called Cotai. Many new, branded casinos and hotels are located in Cotai, such as ‘Venetian Macao’, a magnificent mega-resort owned by the American Las Vegas Sands company.

Sea level rise is posing threats to Macao [42,43]. The sea levels around Macao could rise by 0.72 m by 2100 under the worst scenario (Fox-Kemper et al., 2021). By the end of this century, the temperature will rise 1.4 °C–3.9 °C, and precipitation intensity will increase by 14 % [44]; p.263). Storm surges and severe urban flooding can devastate the city in the event of a supertyphoon. The worst of these was Typhoon Hato.

Typhoon Hato made landfall in Macao on August 23, 2017. The supertyphoon joined an astronomical high tide and raised the maximum tide height to 5.58 m. Seawater intruded the compact city at an unprecedented speed and scale. Storm surges and heavy precipitation caused a 2.5 m flood in the urban centre. The high-density, low-lying Inner Harbour Area at the western part of the Macao Peninsula endured a flood level of 3.1 m (Takagi et al., 2018, [45]. The floods inundated 36.6 % of the land area of the Macao Peninsula [46]; p.134). Typhoon Hato costed Macao MOP12.55 billion (3 % of GDP in 2017) and claimed 10 lives, making it the deadliest natural disaster in the city's modern history [47]; b).

¹ The World Bank: <https://databank.worldbank.org/home.aspx> Accessed 19 August 2022.

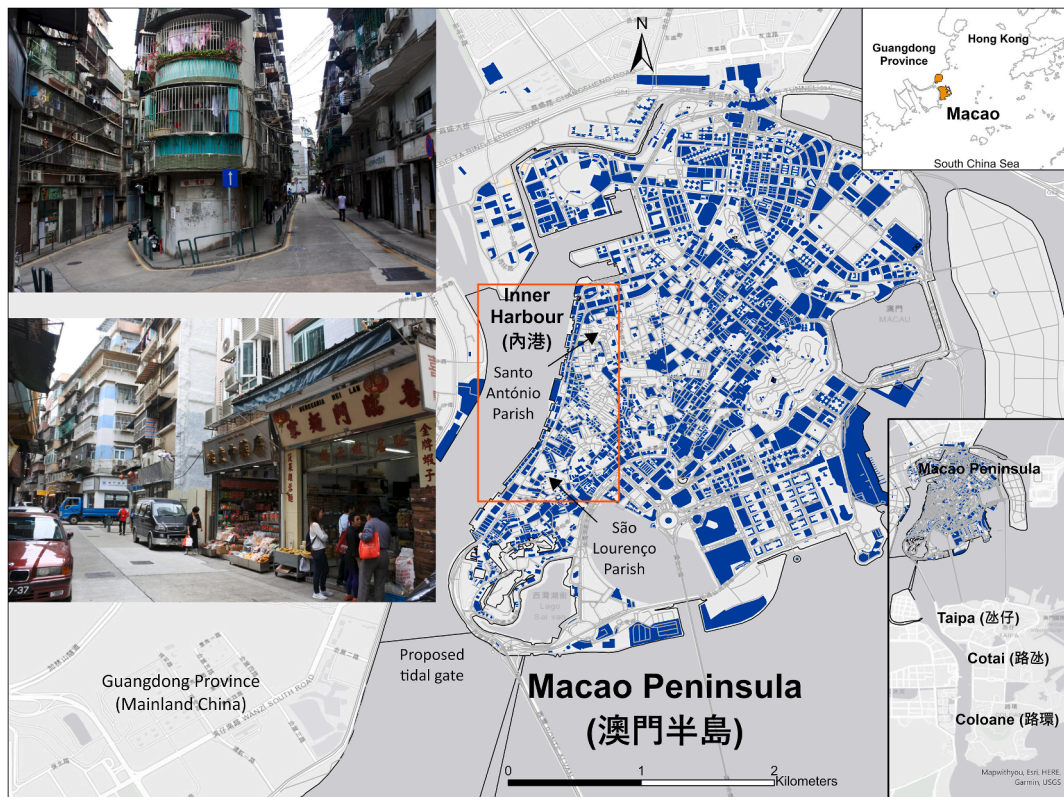


Fig. 1. Map of study area.

4. The case study

We conducted interviews with those who are exposed to the escalating risks of urban inundation due to climate change. In Macao, most residential units are found in multi-storey buildings at a safe vertical distance from floodwater. Ground-level properties are exposed to flooding, and most of them are occupied by businesses. Small retail businesses in the Inner Harbour Area are particularly vulnerable, due to their low-lying location, high density, and limited coping capacities. The high floods triggered by Typhoon Hato damaged hundreds of commercial properties and their assets.

In 2018, the research team organized semi-structured interviews with small business operators to understand the impacts of the 2017 flooding event, their coping and adaptation measures, and their views about government performance, local economy and society. These interviewees were identified in another questionnaire survey undertaken by the research team in December 2017 (see [48, 49], for methodological details). With their consent, we recorded their business location and returned in March 2018 to conduct an in-depth interview with 18 of them (Appendix 1). All of the interviewees operated a retail business in the Inner Harbour Area or an adjacent flood-prone district.

This case study is also based on a review of publicly accessible official statistics and documents, and including statistics yearbooks, population census, parliamentary reports, press releases, post-disaster reports, and government submissions to the United Nations. We report information and statistics that are related to adaptive capacity, such as population density, income distribution, and the area of greenspace. A smaller part of the analysis is informed by the results of a business survey conducted by Lo et al. [48,49].

5. Findings

5.1. The historical context

Before 1999, Macao was a backwater at the margins of Portugal and China [15]. The economy had stagnated for decades. Poor urban planning in colonial years resulted in high population densities in flood-prone areas. In 1991, 342,548 people, or 96 % of the total population, resided in Macao Peninsula. The Inner Harbour Area within Macao Peninsula was always a hotspot for flooding. It includes two densely developed parishes, namely, Santo António and São Lourenço, which had a total population of 154,468 sharing a small continuous area of 1.9 km². In contrast, Taipa and Coloane had an area of 10.9 km², but a small population of 10,314 in 1991 [50]. There was little action to curtail developments around the Inner Harbour Area.

Portuguese settlers dominated Macao's urban governance [51–53]. The colonial political regime marginalized the local Chinese people and lacked visions for long-term planning, as it was set to return Macao's sovereignty to China. After handover, prominent leaders of the local Chinese community form the Macao SAR Government. However, political localization has created a new power hi-

erarchy. Local business elites rise to power and receive a mandate to rule by Beijing's choice. They seek political legitimacy from fast economic growth [53].

The political change in 1999 accelerated the demise of a deeply entrenched political-economic coalition that operated a gaming monopoly for decades. Gaming liberalization in 2002 brought massive foreign investment to the linked gaming and hospitality industries, leading to over a decade of economic boom [53]. In 2019, gaming and junket activities dominated Macao's economy by contributing to 51 % of the gross value added. Gross gaming revenues leapfrogged from MOP23,436 million in 2002 to MOP293,312 million (approx. US\$36,500 million) in 2019 [54]. Massive areas of land have been reclaimed, reproduced, and commodified to make space for new casinos, hotels and resorts [15,17].

5.2. Structure of political economy and urban development

5.2.1. New urban configurations

Macao's economy is structurally skewed toward the gaming industry, resulting in an uneven urban development. The economic boom has driven a dramatic transformation of urban space. Billions of foreign capitals entered Macao to build a settlement for Las Vegas-style casinos, resulting in uneven spatial development. Many small local businesses in the flood-prone areas were left behind: "tourists don't come to here [Horta e Costa near Inner Harbour] ... the Venetian gets all money" (Interviewee #6). The Venetian Macao is located in Cotai, an area of explosive growth.

New developments are concentrated in Taipa and Coloane. Massive new spaces were created in the two districts through large-scale land reclamation from the sea, significantly increasing their total land area from 10.9 km² in 1991 to 21.6 km² in 2021, which includes the Cotai Reclamation Zone created between Taipa and Coloane in the late 1990s. Official statistics presented in Table 2 show that, between 2001 (two years after handover) and 2021, Taipa and Coloane (including Cotai) have gained far more residents, spaces, public roads, and commercial units than Macao Peninsula, indicating the formation of a new urban cluster. The interests of the government and casino concessionaires in commodifying the land and building infrastructure for supporting casinos and resorts are responsible for the fast reproduction of urban space [17].

The Cotai Strip could have been a refuge from flooding. The reclamation zone was initially planned for building a new town that could accommodate over 150,000 residents, which could have absorbed the population growth in the flood-prone Macao Peninsula. However, the SAR Government called off the housing plan and granted the majority of Cotai land to casino concessionaires to enable the newly liberalized gaming industry to thrive [16]. The newly built grand casinos, luxury hotels, and shopping arcades benefit from new taxpayer-funded infrastructure and modern building codes, which can protect them from flooding. In contrast, the waterfront area of Inner Harbour remains poorly flood-proof [46]; p.133). In the 2017 typhoon event, retail trades and restaurants within the facilities of gaming enterprises, which are elevated and protected, recorded a direct economic loss of only MOP\$5 million. The typhoon costed those outside of these facilities, mostly located in Macao Peninsula, a total of MOP\$4168 million, accounting for 46 % of all sectors [47].

The Inner Harbour Area is far from resilient. Santo António and São Lourenço Parishes, both adjacent to Inner Harbour, have recorded a double-digit growth in population density. Floodwater can be extremely dangerous in a high-density environment. To create more space in a tiny piece of land, property developers in Macao have created many small, tightly fitted carparks and storage areas under buildings. These underground spaces have aggravated the failure of the obsolete drainage systems by attracting floodwa-

Table 2

Distribution of population, land area, public roads and commercial units by district in 2001 and 2021.

	Total	Macao Peninsula					Islands	
		Parish					Taipa	Coloane ^a
		Santo António	São Lázaro	São Lourenço	Sé	N.S. de Fátima		
Population (persons)								
2001	435,235**	104,217	26,914	42,841	34,176	180,499	41,786	2904
2021	682,070**	133,920	33,442	53,840	55,275	256,381	112,051	36,384
% Change	56.7	28.5	24.3	25.7	61.7	42.0	168.2	1152.9
Land area (km ²)								
2001	25.8	1.1	0.6	0.9	2.9	3	6.2	11.1
2021	30.8	1.1	0.6	1.0	3.4	3.2	7.9	13.6
% Change	19.4	0.0	0.0	11.1	17.2	6.7	27.4	22.5
Lane length of public roads (km ²)								
2001	315.9	176.7 [#]					139.2	
2021	419.9	203.6 [#]					216.3	
% Change	32.9	15.2 [#]					55.4	
Total number of commercial units								
2004 ^b	41,795	39,496 [#]					1984	315
2021	43,358	40,226 [#]					2507	625
% Change	3.7	1.8 [#]					26.4	98.4

^a includes Cotai reclamation zone; ** includes marine areas but their population estimates are omitted from this table.

^b No pre-2004 official data were found[#] for Macao Peninsula as a whole.

Source: Government of Macao SAR (2002, 2022a, 2022b)

ters, which can quickly inundate assets and people below the ground level. The risk is proven real by Typhoon Hato. The floods killed six people in underground spaces. Nine of the ten fatal events occurred in Macao Peninsula, and the remaining one in Taipa was caused by strong winds and slippery [46]. Flood risks are unevenly distributed between the western part of Macao Peninsula and the recently developed areas in Taipa, Coloane and Cotai. The change in the land development plan for the Cotai Strip was a missed opportunity for redressing the uneven distribution.

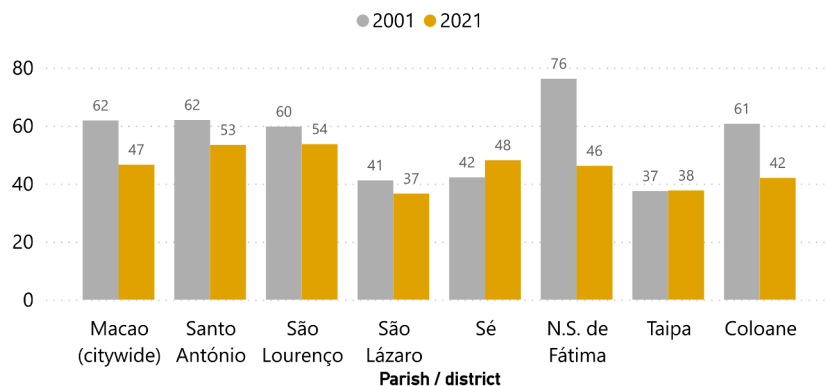
No systematic vulnerability assessment has been conducted for Macao. Nevertheless, there are signs showing that the spatially uneven development strategies have changed the cityscape and demographics in a way that could reduce adaptive capacity.

People's income and assets are key indicators of their capacity for managing risks. We use occupation as a proxy to compare changes in the 20-year period, because we cannot find a district-level breakdown of employment income for 2001. Fig. 2 shows a clear trend of upward mobility during this period. In 2001, flood-prone areas, notably Santo António and São Lourenço, had about 59.7–62 % of their local populations in the lower-income occupation groups, which was close to the city-wide average (61.8 %). In 2021, however, they had a higher percentage of residents in lower-income occupation categories (53.4–53.7 %) than the city as a whole (46.6 %). Taipa and Coloane recorded a marginal change of 0.2 % and a decrease of 18.7 %, respectively. This suggests that there is a comparatively larger share of local residents in the flood-prone areas earning less than the city as a whole.

Vehicle ownership is another indicator. The Inner Harbour Area is extremely compact. Many vehicles are parked in an underground carpark or on the street surrounded by closely packed buildings. In 2017, many of them were severely damaged by the intruding seawater trapped in tight alleys and underground spaces. About 24 % of all buses and over 800 cars and motorcycles were inundated, and five (out of ten) people lost their lives in underground carparks [46]. Vehicle ownership has increased by 14.6 % in 20 years (Fig. 2). A significant part of this growth came from flood-prone areas, including Santo António and São Lourenço Parishes.

Moreover, the supply of green infrastructure is inadequate in the flood-prone areas of Macao. Green areas can reduce stormwater runoff and enhance a city's adaptive capacity. Between 2001 and 2020, however, the amount of green area per land area in Cotai and Taipa increased by 89.1 % and 59.9 % respectively, whereas that of Macao Peninsula was 10.7 % only [55,56].

Percentage of persons in lower-income occupations (%)



Percentage of households with motor vehicles (%)

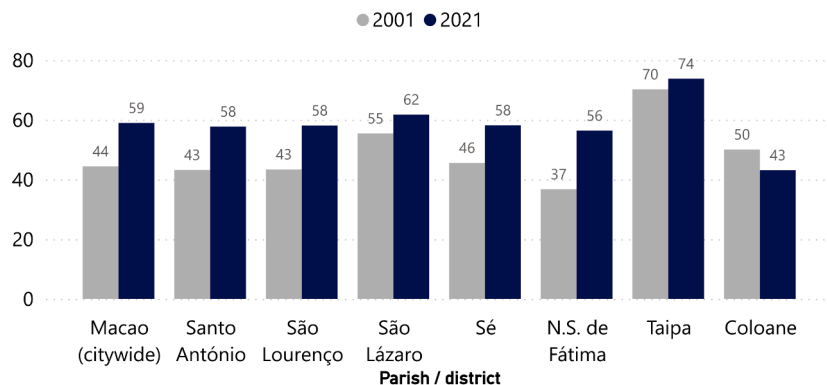


Fig. 2. Distribution of occupations and vehicle ownership by district in 2001 and 2021. Source: Government of Macao SAR (2002, 2022a) Higher-income group includes four occupation types, i.e. 'Directors and managers', 'Professionals', 'Technicians and associate professionals', and 'Clerks' (including croupiers and other casino operational workers). Lower-income group includes four occupation types, i.e. 'Services and sales workers', 'Skilled agricultural and fishery workers', 'Machine operators and drivers', and 'Unskilled workers'. In the lower-income group, median earnings from main employment ranged from MOP3,284 to MOP4,927, whereas in the higher-income group, all median earnings exceeded the city-wide median value, which was MOP5,110 in 2001. * Coloane includes CoTai reclamation zone

The political and economic transformation in Macao since 1999 has turned many resources and institutional attention to the city's new urban spaces. The old ones have become denser and more vulnerable to flooding. Measures for managing flood risks are further compromised by poor governance practice.

5.2.2. Flood risk management

Macao's political-economic structure rewards investment in economic capacity development, but not flood risk management. Typhoon Hato exposed an enduring governance problem. The Macao SAR Government failed to issue early warnings to the public and lacked institutional capacities for managing a meteorological crisis, resulting in delays in evacuation and emergency response, shortage of lifeline supplies and food, and poor inter-departmental coordination [57]; Government of Macao SAR, 2018b; [45]. The poor performance triggered enormous public outrage, forcing the head of Macao's Meteorological and Geophysical Bureau to resign. The lack of accountability and administrative malfunctioning remain deep-seated issues in Macao, as clearly demonstrated by the catastrophe event [57].

Shortly after Typhoon Hato, the Government managed to propose a set of coping and adaptation strategies. Short-term strategies include incremental, soft measures, such as improved rescue operations, early warning systems, and evacuation drills (People's Republic of China, 2018; [45]. Longer-term adaptation would rely on coastal defence infrastructure. The SAR Government proposed a 540 m long tidal gate system to be installed at the mouth of the Wan Chai waterway to protect the Inner Harbour Area from storm surges, which is designed to cope with tidal levels above 3.85 Mean Sea Level and '1-in-200-year' storm surge events [46]. However, the proposed tidal gate system does not constitute a transformative adaptation [43]. contend that the tidal gate, designed according to the maximum water level during Typhoon Hato, would be poorly equipped for adapting to climate change, which can result in higher tides and stronger winds than those observed in 2017.

Since 2017, the SAR Government has been seeking higher-level approvals from the Chinese Central Government and conducting engineering assessments [58], only to find the tidal gate project at risk of significant delay and even abandonment [59]. High costs and rare use were cited as reasons [60]. As the prolonged process of consulting Mainland Chinese authorities continues, the SAR Government has expressed an interest in reinforcing existing engineering measures instead [58].

5.2.3. The social contract

The lack of institutional competence is an outcome of the post-colonial political-economic structure. To legitimize its leadership, the SAR Government has invested considerable monetary and institutional resources in promoting economic growth. The post-colonial Macao pursues capital accumulation by substantially expanding the gaming economy, and governs through informal engagements with major pro-Beijing community groups and tycoons (Lo, 2009; [52]. The SAR Government garners support from these parties by offering them direct economic benefits and other privileges, sometimes at the expense of public interests [61]. The cycle of capitalistic growth is closed by distributing economic dividends derived from the prospering economy to settle public discontent. As a signature policy for managing public expectations, the SAR Government gives away a fixed amount of cash directly to every Macao resident every year since 2008, which has reached MOP\$10,000 (approx. US\$1237) per person in 2022.

Consequently, the state has little incentive for improving governance. It has strategies for regulating political relationships and consolidating support by delivering material benefits, but has limited motivation to enhance accountability and transparency (Lo, 2009, [53]. Development visions are reduced to the advancement of short-term economic interests, whereas the imperative of addressing climate change risks is loosely attached to the cycle of growth in Macao. One of our interviewees succinctly indicated why visions for adaptation have gone missing, when asked if government officials would help them cope with future supertyphoons: "*no, the government won't help. They are opportunistic and only care about money*" (Interviewee #4).

The post-colonial state of Macao has entered into a new social contract with the public. The state rejuvenates the economy by strategically engaging and granting franchises to foreign capitalists to develop newly reclaimed lands into lucrative casinos and resorts. The sweeteners are soaring individual incomes and billions of tax revenues, which are recycled and used to reward pro-government organizations and mitigate public pressures [52,53]; Lo, 2009). In return, the public tolerates institutional incompetence, distributive injustice, and the attenuation of the civil society. The new social contract has perverse incentives for prioritizing short-term material benefits over long-term planning and wider sustainability considerations [15,61,62]. The resulting uneven urban development and economy-first planning principles have contributed to the accumulation of climate change vulnerabilities and a lukewarm response to longer-term adaptation.

5.3. Agency for action and alternative visions

5.3.1. Social change and individuals

The growing materialism and dependence on China threaten to erode the agency of individuals for social action. Macao's post-colonial development pathway is increasingly reliant on the gaming industry. People's incomes have increased, but income inequalities have intensified, and fewer people have trust in the government (Fig. 3).

The gaming industry offers remarkably attractive remuneration for unskilled labours with little work experience. The combination of low entry requirements and high returns has driven young people away from tertiary education and resulted in high dropout rates at schools [17,62]. Materialism is widespread among the younger generations and within the society generally. As an interviewee (#1) lamented with a cynical tone: "*Macao [people] doesn't care, as long as there is money for them*", or "*realistic, money first*" in the words of Interviewee #2. Once a charming city of history and heritage [15,17], Macao has been reduced to a place for personal economic advancement and consumption.

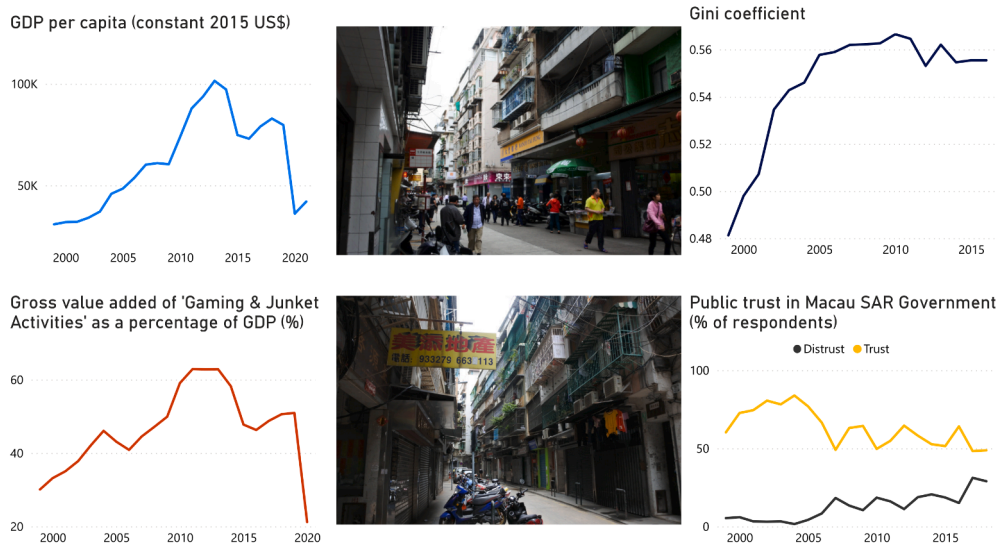


Fig. 3. Selected indicators of social and economic change in Macao. GDP per capita (constant 2015 US\$). Source: The World Bank (<https://data.worldbank.org>). Gross value added of 'Gaming & Junket Activities' as a percentage of GDP. Source: Government of Macao SAR (2022b). Both GDP per capita and gross value added show a sharp decline in 2020 and 2021, due to the impact of COVID-19 on inbound tourism. Gini coefficient. Source: World Inequality Database (<https://wid.world/country/macao/>). Public trust. Source: Public Opinion Program's Macao Annual Survey, The University of Hong Kong (<https://www.hkpop.hku.hk/chinese/popexpress/macao/index.html>). Accessed August 15, 2022. Survey statement: 'On the whole, do you trust the Macao SAR Government?' Response options: 'Very trust', 'Quite trust', 'Half-half', 'Quite distrust', and 'Very distrust'. In the graph above, 'Trust' includes 'Very trust' and 'Quite trust', and 'Distrust' includes 'Quite distrust' and 'Very distrust'. 'Half-half' is omitted.

Small businesses outside gaming facilities suffered significant losses in the 2017 typhoon event. Many business operators have taken preventive individual action and become concerned about the escalating risks of flooding and typhoons in the next 20 years. However, their sense of place was weaker than other tourist destinations we studied, and they were the least likely to believe that the government and lawmakers would help residents cope with future typhoon events (Appendix 2). This reflects a widespread decline in local people's trust in the Macao SAR Government (Fig. 3).

The twenty years of development have made Macao more dependent on Mainland China. Most migrants originally come from the Mainland. The massive gaming revenues, jobs, and other business opportunities are derived from the spendings of transboundary tourists, predominantly from the Mainland. Macao's economic success is therefore inseparable from the discretionary policy decisions of the Chinese Central Government, which acts as a shadow regime, such as the number of travel permits granted to Mainland Chinese residents for visiting Macao. Moreover, China plays an important role in Macao's recovery from, and adaptation to, natural hazards. For example, in the 2017 typhoon event, the Central Government was given credits for deploying armies to help remove debris and offering lifeline supplies, whereas the interventions by the Macao SAR Government were sluggish. Power outage in a typhoon event requires Chinese authorities to help restore, because Macao imports most of its electricity from Mainland China. Permission by the Central Government is essential for the construction of the Inner Harbour tidal gate. The externalization of development opportunities and responsibilities has turned the agents of change away from Macao.

The rise of materialism, weak sense of place, lack of institutional trust, and dependence on China alienate individuals from debates on issues of low economic and political urgency, such as climate change. Public discussions on climate change are patchy, and even flood victims are not engaging: "climate change is an 'out of touch' issue. How can individuals offer any opinion?" (Interviewee #18).

5.3.2. The civil society and climate policy

The limited agency for change of the civil society is aggregated by the demise of oppositional green politics. A new power hierarchy has emerged in Macao, although the governing power has returned to the Chinese community since 1999. Pro-Beijing community leaders and business elites are privileged, whereas the civil society has not come to challenge the Government's incremental approach to adaptation.

Macao's residents directly elect less than half of the seats in the legislature and have little influence on the leadership choices made by the Chinese Central Government. Formal policy-making processes are overshadowed by a consensus politics characterized by informal interactions among powerful political and economic interest groups [52,53]. People's frustration at the lack of transparency has accumulated since the handover. In 2014, the civil society organized mass protests and forced the government to withdraw unpopular bills. In the 2017 general election, people turned their votes to oppositional democratic candidates, leading to their unprecedented electoral success. However, these democrats were barred from the 2021 election. Pressure groups and mass mobilization are discouraged by tighter restrictions. Political pluralism has come to a demise in its infancy.

Consequently, there is little space for climate change advocacy and activism to grow. Younger left-wing activists, including those elected in 2017, are broadly concerned about sustainability issues and could have advocated for changes that recognize climate change risks, as in the neighbouring city of Hong Kong [9]. However, the Chinese elites who govern the city politically depend on Mainland China and resist alternative, liberal visions that could pose challenges to its legitimacy, such as deepening democratization. Conservative forces and business interest groups continue to have asymmetric influences on politics and policy. Liberal-minded activists and NGOs have limited ability to lobby for integrating anticipatory approaches of climate change adaptation into politics and policy.

Liberal environmental discourses struggle to influence the government's policy agenda under the exclusive and pro-growth politics. The SAR Government's environmental protection plans do not explicitly address climate change adaptation [63,64]. Macao is included in China's National Communication on Climate Change submitted to the UNFCCC. Both the 2012 and 2018 submissions indicate that Macao's adaptation strategies remain initial and incomplete [65]; p.198; 2018, p.265). The core measures for dealing with sea level rise involved flood-proofing electric power facilities, improving early warning systems, and building a tidal gate. Only the tidal gate can be seen as a medium-to-long-term solution. There are pressures from within the legislature for accelerating the construction work, but the agency for change rests upon the administration and the shadow regime, i.e., China [58].

6. Discussion

The above analysis focuses on political and development trajectories to understand a high-income city's vulnerability to climate change. Planned political decolonization and localization resulted in a new regime that succeeded in accelerating economic growth. The political and economic transformation have shaped social structures and agency in a way that has led to a reduction of some vulnerabilities, but an increase in others.

The social structures of Macao are maladaptive to climate change. Political decolonization resulted in a new power hierarchy endorsed by a higher governing authority. By formally liberalizing the gaming market and allowing the gaming industry to dominate the economy, the post-colonial regime has institutionalized a development pathway that builds casino-based tourism deep into the city's economic structure. The concentration of investments and revenues in tourism establishments and clusters has drawn institutional attention to the new casino town of Cotai and away from the older urban areas that have higher densities and vulnerabilities to storm surges. The failure of existing governing institutions in reducing vulnerability exacerbated the consequences of the catastrophic flooding event in 2017.

The agency for change has been undermined. Activists challenged the prevailing systems and created pressures for change. The oppositional civil society proposed alternative development visions and gained a public mandate. However, the main area of conflict has been social issues, rather than the environment. The public has engaged in a perverse social contract that prioritizes short-term economic gains, and has developed tolerance to institutional failures. The political-economic transformation has reproduced a hegemonic structure that perpetuates this state-society relationship and is resilient to public outrage. The ability to re-negotiate this perverse social contract is constrained by a superior constitutional authority.

The city of Macao is situated between the first two phases of adaptive cycle, namely, 'institutionalized' and 'scattered' [37]. The structure of the political economy is cohesive, and the prevailing development discourse remains dominant. Capitalist development has generated a flow of economic dividends that enable the state to manage public expectations and limit people's agency for promoting alternative agendas. Major institutional failures resulted in counter-hegemonic development visions that could have led to a departure from the established norms and structures. However, the transition towards scattered is incomplete. The power relations between the state and civil society remain highly unequal, and the social agents for influencing policy practice are marginalized. Mediated by this power dynamics, the re-negotiation of development visions and political futures remains departed from climate change goals.

This case study shows how a re-routing of a development pathway has created an ambivalent impact on climate change vulnerability. Transformation of wider political, economic and social systems changes everything, but not every change falls within a desirable range [66]. The formation of a market economy can help alleviate poverty and the rolling back of the state may encourage collective social response to coastal hazards, but it can also increase vulnerability by concentrating resources in a handful of people [7]. Tourism development attracts investments and makes a strong economic case for implementing managerial and technological measures for coping with coastal hazards, but a shift towards mass tourism can undermine the influence of civil society in advancing a resilient development pathway [35]. Our findings suggest that structural changes to the political economy can increase vulnerability by perpetuating the uneven distribution of resources and benefits. Without addressing unequal power relations, fundamental shifts may reproduce, rather than eliminate, deep-seated patterns of uneven distribution that create vulnerability [13].

This study makes a conceptual contribution by deconstructing the perceived legitimacy of a transforming system in addressing the relationship between transformation and vulnerability reduction. The findings contribute to the transformation discourse by questioning who legitimizes a system transformation and examining how legitimization influences the conditions for vulnerability reduction. We suggest that new or altered system components can reproduce vulnerability in the process of performance legitimization. In doing so, we also critically reflect on the contested role of social contract in climate change adaptation. Political decolonization has removed the colonial power hierarchy, but created a new power hierarchy privileging pro-Beijing elites. These governing elites seek political legitimacy primarily from extraordinary economic performance [39].

Performance legitimization entails a social contract. Macao's citizens benefit from fast economic growth, but conform to the rules that constrain their ability to hold the administration accountable and select their preferred leaders (Lo, 2009; [53]). This effectively legitimizes both a pro-growth development model and a reduced form of democracy, which can lock the social structures and

social agents in a pathway that is poorly set for enabling vulnerability reduction. The aftermath of the supertyphoon could trigger a re-negotiation of the perverse social contract. There are strong theoretical justifications for promoting such a negotiation as a transformative process for addressing climate change challenges [67,68]. However, re-negotiation requires that citizens or their representatives possess the means of negotiation, such as the ability to remove elected officials, the rule of law, and a mandate to govern, which are shrinking in Macao [69]. The historic social change has perpetuated the imbalance of power between citizens and the state.

Demonstrating advantages over its predecessors is essential for a system's fundamental restructuring to occur and sustain. New or altered system components that are legitimized by an unsustainable practice risk undermining the capacity of social structures and social agents for redressing institutional failures and pursuing alternative development strategies. The relationship between transformation and vulnerability reduction is non-linear. The effects of transformative social change are conditioned upon socio-political realities. The process of legitimizing a deliberate radical change, the state-society negotiation, and the power relations involved influence the capacity of a transforming system for adapting to climate change.

7. Conclusions

This article answers the broad question of 'what mechanisms of a system transformation increase people's vulnerability to climate change?' The study of post-colonial Macao has shown how political-economic transformation has affected the capacity of a high-income city for managing storm surges. This unique case study helps understand the relationship between system transformation and climate change vulnerability reduction.

We conclude that a transformation that seeks legitimacy from an unsustainable practice is a recipe for maladaptation. Transformation is differentiated from transformative adaptation. Transformative adaptation requires a social change process that is deliberately driven toward desirable ends and entails transforming systems and structures. Climate change is understood as "the drive for transformation" [18]; p.7).

System transformation is more often driven by competing socio-economic priorities than climate change goals. Some adaptation actions are described as transformative, but it is not clear whether the transformations reported constitute enduring changes in the entire system over a long timeframe. There is little emphasis on the scale and duration of transformative action (Nalau and Hander, 2015). Enduring system changes, such as a change of sovereignty and economic transition, can shift development pathways and radically alter social structures, institutions, and power relations, but those that have the scale, depth, and energy to do so are rarely driven by climate change goals alone. This leaves us with little empirical evidence on system-level transformative adaptation that demands greater depth and breadth of change.

Analyzing the broader and disruptive processes of transformation as a determinant offers an alternative framing for adaptation studies, which tend to conceptualize transformation as an ideal outcome, e.g., transformative adaptation. Such a systemic analysis will examine the enduring processes and pervasive impacts of political, economic and social transformation over a longer timeframe to identify factors that influence the conditions for adaptation. These processes and impacts determine general or 'starting-point' vulnerability (O'Brien et al., 2007) and may occur at the society level beyond functionally delimited systems, such as a single community and industry [22]. There are lessons from Refs. [5,7,35]; and Goulden et al. (2013). Acknowledging the socio-temporal dimension of these processes and impacts, which includes their history, timing, and longevity, is crucial for understanding the non-linear relationship between transformation and vulnerability reduction.

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CRediT authorship contribution statement

Alex Y. Lo: Conceptualization, Formal analysis, Investigation, Writing – original draft. **Shuwen Liu:** Investigation, Project administration, Writing – review & editing. **Lewis T.O. Cheung:** Funding acquisition, Project administration, Resources, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijdr.2023.104234>.

References

- [1] W.L. Filho, F. Wolf, S. Moncada, A.L. Salvia, A.-L.B. Balogun, C. Skanavis, A. Kounani, P.D. Nunn, Transformative adaptation as a sustainable response to climate change: insights from large-scale case studies, *Mitig. Adapt. Strategies Glob. Change* 27 (2022) 20.
- [2] S.D. Mauritsch, F.Z. Fahmi, D.S.A. Suroso, Transformative resilience: transformation, resilience and capacity of coastal communities in facing disasters in two Indonesian villages, *Int. J. Disaster Risk Reduc.* 88 (2023) 103615.
- [3] K. O'Brien, Global environmental change II: From adaptation to deliberate transformation, *Prog. Hum. Geogr.* 36 (2012) 667–676.
- [4] J. Blythe, J. Silver, L. Evans, D. Armitage, N.J. Bennett, M.-L. Moore, T.H. Morrison, K. Brown, The dark side of transformation: latent risks in contemporary sustainability discourse, *Antipode* 50 (2018) 1206–1223.
- [5] M. Pelling, *Adaptation to Climate Change: from Resilience to Transformation* Routledge, 2011 Oxon, U.K.
- [6] M. Pelling, K. O'Brien, D. Matyas, *Adaptation and transformation*, *Climatic Change* 133 (2015) 113–127.
- [7] W.N. Adger, Social vulnerability to climate change and extremes in coastal vietnam, *World Dev.* 27 (1999) 249–269.
- [8] W. Handayani, R. Setiadi, B. Septiarani, L. Lewis, Metropolitan Semarang: clustering and connecting locally championed metropolitan solutions, in: *Greater than Parts Case Study*, No. 8, World Bank, Washington, DC, 2020.
- [9] A.Y. Lo, S. Liu, L.T.O. Cheung, F.K.S. Chan, Contested transformations: sustainable economic development and capacity for adapting to climate change, *Ann. Assoc. Am. Geogr.* 110 (2020) 223–241.
- [10] D. Marks, L. Lebel, Disaster governance and the scalar politics of incomplete decentralization: fragmented and contested responses to the 2011 floods in Central Thailand 52 (2016) 57–66.
- [11] R. Setiadi, R. Frederika, Family financial planning for disaster preparedness: a case study of North Semarang, Indonesia, *Int. J. Disaster Risk Reduc.* 82 (2022) 103332.
- [12] J. Nalau, J. Handmer, When is transformation a viable policy alternative? *Environ. Sci. Pol.* 54 (2015) 349–356.
- [13] S. Eriksen, E.L.F. Schipper, M. Scoville-Simonds, K. Vincent, H.N. Adam, N. Brooks, B. Harding, D. Khatri, L. Lenaerts, D. Liverman, M. Mills-Novoa, M. Mosberg, S. Movik, B. Muok, A. Nightingale, H. Ojha, L. Sygna, M. Taylor, C. Vogel, J.J. West, Adaptation interventions and their effect on vulnerability in developing countries: help, hindrance or irrelevance? *World Dev.* 141 (2021) 105383.
- [14] R. Gillard, A. Gouldson, J. Paavola, J. Van Alstine, Transformational responses to climate change: beyond a systems perspective of social change in mitigation and adaptation, *WIREs Climate Change* 7 (2016) 251–265.
- [15] C.L. Chu, Spectacular Macau: visioning futures for a world heritage city, *Geoforum* 65 (2015) 440–450.
- [16] M. Sheng, C. Gu, Economic growth and development in Macau (1999–2016): the role of the booming gaming industry, *Cities* 75 (2018) 72–80.
- [17] T. Simpson, Macao, capital of the 21st century? *Environ. Plann. Soc. Space* 26 (2008) 1053–1079.
- [18] R. Few, D. Morchain, D. Spear, A. Mensah, R. Bendapudi, Transformation, adaptation and development: relating concepts to practice, *Palgrave Communications* 3 (2017) 17092.
- [19] S.H. Eriksen, A.J. Nightingale, H. Eakin, Reframing adaptation: the political nature of climate change adaptation, *Global Environ. Change* 35 (2015) 523–533.
- [20] K. O'Brien, S. Eriksen, T.H. Inderberg, L. Sygna, Climate change and development: adaptation through transformation, in: T.H. Inderberg, S. Eriksen, K. O'Brien, L. Sygna (Eds.), *Climate Change Adaptation and Development: Transforming Paradigms and Practices*, Routledge, London, 2014, pp. 273–289.
- [21] U. Pascual, P.D. McElwee, S.E. Diamond, H.T. Ngo, X. Bai, W.W.L. Cheung, M. Lim, N. Steiner, J. Agard, C.I. Donatti, C.M. Duarte, R. Leemans, S. Managi, A.P.F. Pires, V. Reyes-García, C. Trisos, R.J. Scholes, H.-O. Pörtner, Governing for transformative change across the biodiversity–climate–society nexus, *Bioscience* 72 (2022) 684–704.
- [22] T.M. Deubelli, R. Mechler, Perspectives on transformational change in climate risk management and adaptation, *Environ. Res. Lett.* 16 (2021) 053002.
- [23] S.E. Park, N.A. Marshall, E. Jakkui, A.M. Dowd, S.M. Howden, E. Mendham, A. Fleming, Informing adaptation responses to climate change through theories of transformation, *Global Environ. Change* 22 (2012) 115–126.
- [24] L. Shi, S. Moser, Transformational climate adaptation in the United States: trends and prospects, *Science* 372 (2021) eabc8054.
- [25] S.J. O'Neill, Responding to bushfire risk: the need for transformative adaptation, *Environ. Res. Lett.* 7 (2012) 014018.
- [26] L. Rickards, Transformation is adaptation, *Nat. Clim. Change* 3 (2013) 690.
- [27] A.J. Nightingale, N. Gonda, S.H. Eriksen, Affective adaptation = effective transformation? Shifting the politics of climate change adaptation and transformation from the status quo, *WIREs Climate Change* 13 (2022) e740.
- [28] W. Merkel, R. Kollmorgen, H.-J. Wager, Transformation and transition research: an introduction, in: W. Merkel, R. Kollmorgen, H.-J. Wager (Eds.), *The Handbook of Political, Social, and Economic Transformation*, Oxford University Press, New York, NY, 2019, p. 1.
- [29] R. Few, K. Brown, E.L. Tompkins, Public participation and climate change adaptation: avoiding the illusion of inclusion, *Clim. Pol.* 7 (2007) 46–59.
- [30] B. Hayward, 'Nowhere far from the sea': political challenges of coastal adaptation to climate change in New Zealand, *Polit. Sci.* 60 (2008) 47–59.
- [31] Y. Okura, C. Tamang, S. Pandit, J. Stone, Transformational adaptation of communities through systems development, in: *The Palgrave Handbook of Climate Resilient Societies*, Springer International Publishing, Cham, 2020, pp. 1–24.
- [32] S. van Bommel, C. Blackmore, N. Foster, J. de Vries, Performing and orchestrating governance learning for systemic transformation in practice for climate change adaptation, *Outlook Agric.* 45 (2016) 231–237.
- [33] G. Ziervogel, J. Enqvist, L. Metelerkamp, J. van Breda, Supporting transformative climate adaptation: community-level capacity building and knowledge co-creation in South Africa, *Clim. Pol.* 22 (2022) 607–622.
- [34] J. Barnett, S. O'Neill, Maladaptation, *Global Environ. Change* 20 (2010) 211–213.
- [35] D. Manuel-Navarrete, M. Pelling, M. Redclift, Critical adaptation to hurricanes in the Mexican Caribbean: development visions, governance structures, and coping strategies, *Global Environ. Change* 21 (2011) 249–258.
- [36] A.Y. Lo, S. Liu, L.T.O. Cheung, Socio-economic conditions and small business vulnerability to climate change impacts in Hong Kong, *Clim. Dev.* 11 (2019) 930–942.
- [37] M. Pelling, D. Manuel-Navarrete, From resilience to transformation the adaptive cycle in two Mexican urban centers, *Ecol. Soc.* 16 (2011).
- [38] T.H. Morrison, W.N. Adger, A. Agrawal, K. Brown, M.J. Hornsey, T.P. Hughes, M. Jain, M.C. Lemos, L.H. McHugh, S. O'Neill, D. Van Berkel, Radical interventions for climate-impacted systems, *Nat. Clim. Change* 12 (2022) 1100–1106.
- [39] Y. Zhu, "Performance legitimacy" and China's political adaptation strategy, *J. Chin. Polit. Sci.* 16 (2011) 123–140.
- [40] Government of Macao SAR, Yearbook of Statistics 2020, b edn., Statistics and Census Service, Macao, 2021.
- [41] Government of Macao SAR, Population Census 2021, Statistics and Census Service, Macao, 2022.
- [42] L. Li, A.D. Switzer, Y. Wang, C.-H. Chan, Q. Qiu, R. Weiss, A modest 0.5-m rise in sea level will double the tsunami hazard in Macau, *Sci. Adv.* 4 (2018) eaat1180.
- [43] J. Yang, M. Chen, Potential impacts of flood risk with rising sea level in Macau: dynamic simulation from historical Typhoon Mangkhut (2018), *Ocean Engineering* 246 (2022) 110605.
- [44] People's Republic of China, The People's Republic of China's Third National Communication on Climate Change of (Submitted to the UNFCCC), The People's Republic of China, Beijing, 2018.
- [45] H. Takagi, X. Yi, J. Fan, Public Perception of Typhoon Signals and Response in Macau: Did Disaster Response Improve between the 2017 Hato and 2018 Mangkhut Typhoons? *Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards*, 2021, pp. 1–7.
- [46] Government of Macao SAR, Assessment of the overall impact of Typhoon Hato and suggestions for optimising Macao's mechanism for managing emergencies. Direcção dos Serviços de Estudo de Políticas e Desenvolvimento Regional, 2018 Available from: <https://www.dsepd.gov.mo/uploads/attachment/2020-05/827cd17ec92228c657ec185036a29c90.pdf>. (Accessed 8 July 2022). Macao.
- [47] Government of Macao SAR, 23rd Typhoon Caused Macao an Estimated Economic Loss of MOP12.55 Billion, vol. 8, Government of Macao SAR, Macao, 2018 Available from: <https://www.gov.mo/en/news/92355/>. (Accessed 8 July 2022).
- [48] A.Y. Lo, S. Liu, A.S.Y. Chow, Q. Pei, L.T.O. Cheung, L. Fok, In government we trust? Micro-business adaptation to climate change in four post-colonial and transitional economies of China, *Global Environ. Change* 69 (2021) 102305.

- [49] A.Y. Lo, A.S.Y. Chow, S. Liu, L.T.O. Cheung, Community business resilience: adaptation practice of micro- and small enterprises around the Pearl River Estuary, *Climatic Change* 157 (2019) 565–585.
- [50] Department of Macao, Population Census 1991, Statistics and Census Service, Macao, 1993.
- [51] J. Porter, The transformation of Macau, *Pac. Aff.* 66 (1993) 7–20.
- [52] L. Sheng, The transformation of island city politics: the case of Macau, *Island Studies Journal* 11 (2016) 521–536.
- [53] L. Sheng, P.Y.K. Wan, Explaining urban governance in the midst of political transformation: the city of Macao, *Asia Pac. Viewp.* 58 (2017) 289–300.
- [54] Government of Macao SAR, Statistics. Statistics and Census Service, 2022 Available from: <https://www.dsec.gov.mo/en-US/>. (Accessed 8 July 2022). Macao.
- [55] Government of Macao SAR, Environment Statistics 2002, Statistics and Census Service, Macao, 2003.
- [56] Government of Macao SAR, Environment Statistics 2020, a edn., Statistics and Census Service, Macao, 2021.
- [57] K.-S. Chan, Z.-x. Zheng, R.-l. Gong, A study on crisis management of typhoon Hato in Macau, *Journal. Mass Commun.* 8 (2018) 1–12.
- [58] Legislative Assembly of Macao, Comissão de Acompanhamento para os Assuntos de Terras e Concessões Públicas (土地及公共批給事務跟進委員會), Legislative Assembly of Macao, Macao, 2019 Report 2/VI/2019.
- [59] Journal Cheng Pou, Inner Harbour floodgate may not go ahead, <http://www.chengpou.com.mo/dailynews/189815.html>, 2020. (Accessed 25 July 2022).
- [60] Macao Daily, The Inner Harbour Floodgate Is a 'big White Elephant'. 1st December, Macao Daily, Macao, 2021 Available from: http://www.macaodaily.com/html/2021-12/01/content_1560491.htm. (Accessed 25 July 2022).
- [61] Y.K.P. Wan, The social, economic and environmental impacts of casino gaming in Macao: the community leader perspective, *J. Sustain. Tourism* 20 (2012) 737–755.
- [62] Y.K.P. Wan, X. Li, Sustainability of tourism development in Macao, China, *Int. J. Tourism Res.* 15 (2013) 52–65.
- [63] Macao Environmental Protection Bureau, Environmental Protection Planning of Macao (2010-2020), Macao Environmental Protection Bureau, Macao, 2012.
- [64] Macao Environmental Protection Bureau, Environmental Protection Planning of Macao (2021-2025), Macao Environmental Protection Bureau, Macao, 2022.
- [65] People's Republic of China, The People's Republic of China's Second National Communication on Climate Change of (Submitted to the UNFCCC), The People's Republic of China, Beijing, 2012.
- [66] J. Pickering, T. Hickmann, K. Bäckstrand, A. Kalfagianni, M. Bloomfield, A. Mert, H. Ransan-Cooper, A.Y. Lo, Democratising sustainability transformations: assessing the transformative potential of democratic practices in environmental governance, *Earth System Governance* 11 (2022) 100131.
- [67] W.N. Adger, T. Quinn, I. Lorenzoni, C. Murphy, J. Sweeney, Changing social contracts in climate-change adaptation, *Nat. Clim. Change* 3 (2013) 330–333.
- [68] K. O'Brien, B. Hayward, F. Berkes, Rethinking social contracts building resilience in a changing climate, *Ecol. Soc.* 14 (2009).
- [69] M.Y.H. Wong, Y.-h Kwong, One formula, different trajectories: China's coalition-building and elite dynamics in Hong Kong and Macau, *Crit. Asian Stud.* 52 (2020) 44–66.