Selected global flood preparation and response lessons: implications for more resilient Chinese Cities

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Abstract

Global urban populations are rising, and more extreme climate events occur, which means more people are exposed to flood hazards such as pluvial, fluvial, and coastal or compound floods with all of these types of floods. Cities located in flood-prone areas besides the coasts, rivers, or both are at higher risk because natural and engineered systems have insufficient water storage capacity to offload peak discharge and withstand the surge levels. Whilst the combined drives with non-climatic factors and climatic factors such as urbanisation and social-economic developments, and increasing extreme rainfall patterns, storms, surges, and Global mean-sea level rise are unstoppable. That is doubtful still to rely on improving flood protection to secure resilience. We focused on reviewing the lessons from flood responses globally for the major events in the last decade. More core options such as understanding the importance of responding to flooding events and improving the risk communication between the stakeholders, administration, and the public seem to be the key to minimising the flood impacts on the communities. Under the continuous growth of human exposure, we suggest an urgent call for authorities to enact a better flood response strategy in their flood disaster risk reduction plans and policies. These lessons and implications for improving the resilience of Chinese cities and elsewhere.

Keywords

Flood, global cities, response and resilience

Introduction

Global human settlements are increasing significantly on the waterfronts besides the coasts and rivers (Magnan et al., 2022) with over 325 million people living in coastal cities and urban flood-prone areas in Asia (McGranahan et al., 2007). The global urban population has almost increased threefold, reaching 3.98 billion in the 2020s (Varis et al., 2022). Such developmental progress and pressure have boosted the communities under higher flood risk in the flood and storm-prone urban areas (Lu et al., 2022). The recent Intergovernmental Panel on Climate Change (IPCC) projected climatic extremes such as more intense rainstorms and surges and mean Sea-Level Rise in the next few decades (Tangney, 2020). That means more people will be exposed to urban pluvial, fluvial and coastal floods due to the high density of influenced populations in global cities (Swiss Re, 2014). Flood disasters continue to have detrimental impacts on the livelihoods and well-being of people, owing to a lack of sufficient resources for flood protection, preparedness, response and recovery. This includes the absence of leveraging reliable flood risk assessment practices that have commonly affected the devastating impacts on livelihoods in the Global South (GS) and their cities such as Dhaka, Yangon, Ho Chi Minh City, Jakarta, etc. Most of the GS cities are still lacking post-flood recovery supporting systems such as flood insurance (Rentschler et al., 2022).

Indeed, floods are the most frequent and catastrophic natural disasters among all other natural hazards (Berz et al., 2001), which cost a global annual global loss reached at US$100 billion (Bhatt et al., 2017) and affected more than 1.4 billion people including than 100,000 casualties from floods in the late 1990s to 2000s (Jonkman, 2007; Jonkman and Vrijling, 2008). In the last decade (from the 2010s to now), we know that various magnitudes of floods occur yearly. For example, large floods visited Pakistan just in August 2022), India and China (e.g. Zhengzhou flood in 2021) in the last decade (Merz et al., 2021; Rentschler et al., 2022). For example, Pakistan experienced the worst floods; at least two-thirds of the country's districts have been flooded, displacing some 33 million people and causing more than 1500 casualties. The situation was exacerbated because of the ice-melted glaciers in the northern mountainous regions of the Himalayans regions, plus the low air pressure caused heavy rain from the Arabian Sea that precipitated three times more than its average annual rainfall for the monsoon period to compare previous years (Mallapaty, 2022). In China, a disastrous flood occurred in Zhengzhou (and also the Northern Plain of China) on 20 July 2021 with a record-breaking rainstorm event accumulating over 700mm within 24 hours which was categorised as a 1-in-1000-year storm event that caused 293 casualties and a total economic lost at 114.2 billion RMB (about USD 18 billion at 2021 rate)(Chan et al., 2022a). Across Africa, the 2022 Nigeria flood destroyed over 70,000 hectares of farmland, damaged more than 45,000 households and displaced over 1.4 million Nigerians with over 500 casualties reported (Asadu, 2022). We fully understand that it is impossible to improve flood resilience overnight, such as by increasing flood protection measures (e.g. improving flood measures – flood embankments, walls, drainage systems, building dams, etc.). In a short time, even if the financial limitations are resolved (as the engineered infrastructure is expensive and time-consuming, e.g. the urban drainage system in Hong Kong took over 10 years from the 1990s – 2000s)(Chan et al., 2021a). Thus, one of the most effective ways to resilience is to improve flood preparedness and response.

For example, in the last decade, technological-driven factors are benefiting these measures with the popularity of social media, the Internet, mobile (smart) phones and their apps via information communication technology (ICT) (Paciarotti et al., 2018) that forester the stakeholders and communities to enable the effectiveness on the flood emergency and disaster response that share flood information and communicate during flood emergencies. For example, release the latest flood warnings and conditions and information on relocation and rescue services. Whilst, the response function essentially reduces loss of life and includes actions on limiting injuries, damage to property and infrastructure and the environment and is taken before, during, and immediately after a hazard event occurs (Yin et al., 2020). Flood response is the most complex emergency management function, conducted under high stress, in a time-constrained environment, and with limited information(Lai et al., 2020). In terms of a flood, emergencies might be diverted into three phases, with several response activities applying to each. These include hazard, the emergency–hazard effects are ongoing, and the emergency–hazard effects have ceased. The flood response practice begins as soon as the flood hazard is detected (Merz et al., 2010). That merge with the pre-disaster response actions, such as flood warning and evacuation during the floods, prepositioning of resources and offering last-minute mitigation (e.g. relocation and rescue actions) and preparedness. Once a hazard event begins and is recognized, response efforts commence in earnest.

Undeniably, the priority of setting up flood response practices, is saving lives (may continue for days or weeks) (Wang et al., 2020). As resources are mobilised, the following functions may be added in increasing priority: search and rescue; first aid medical treatment; evacuation; disaster assessments; hazard treatment; provision of water, food, and shelter; health; sanitation; safety and security; critical infrastructure resumption; emergency social services; and donations management. Coordination and Co-production are vital and immediate components of international disaster response because of the sheer number of agencies that descend on the affected areas (Cooke et al., 2021). We emphasised that non-structural response measures (e.g. warning instructions and technologies, information and communication channels, insurance, etc.) are effective and retained at lower cost compare to structural response measures (e.g. flood defence constructions – dams, polders, channelisation, dredging rivers, dikes, levees, embankments, flood walls), these constructions measures are still important but highly expensive and often take a long period for the engineering projects completion that might not be "cost-effective" and effectively reduce the according injuries and casualties. Since the late 1990s, the Institute of Civil Engineering (ICE) has also promoted the combined approaches to adopt the "mixed approaches" that combine the soft and hard flood response and mitigation measures in the UK (Fleming, 2002).

Our study fills critical review gaps on flood response, mainly, to provide a global-scale and long-term synthesis on human inhabitants in urban areas; secondly, this paper also focuses on the global scale or long-term synthesis of human health/risk caused by flooding. Because of the major objectives, particularly how to merge practices from the Sendai Framework and reduce the flood risk and disasters that mitigate the according impacts for vulnerable communities (see figure 1). Lastly, we push the flood response and the relationship with the "Sendai Framework" (and relevant frameworks) for improving flood/climate resilience.

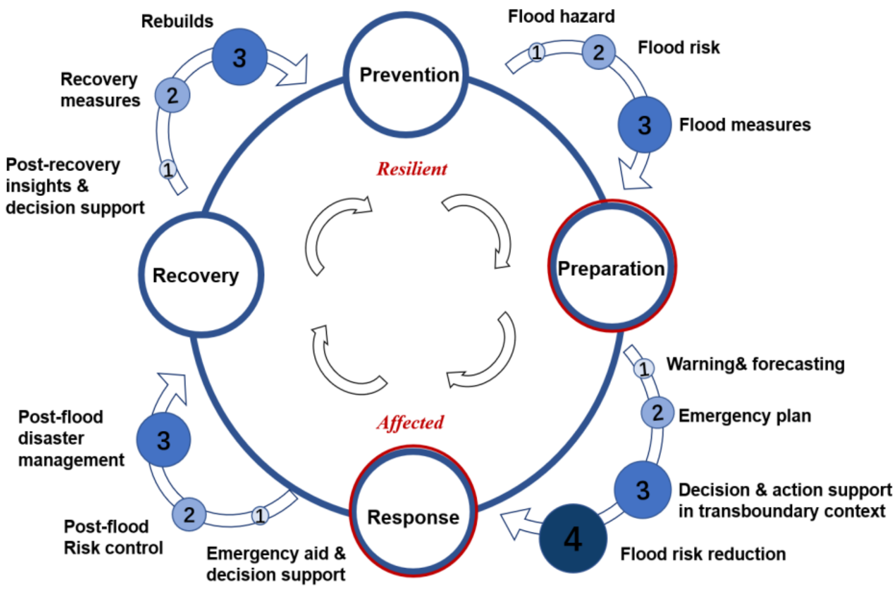

Figure 1 Flood resilience schematic diagram with prevention, preparation, response and recovery. (Source adapted from Heuer and Chan et al. 2021)

Recent Global flood disaster: Lessons?

1. South Asia - Pakistan flood 2022 and India flood 2018

Pakistan has experienced the wettest heavy downpours since 1961 and the rainfall has been 5 times above the average of late August annually by this weather extreme event. Whilst, the flood has also contributed to the melted glaciers from Northern/North-Eastern Himalayan regions, which have become more vulnerable to ice-melting and sudden outbursts of melted glaciers (Mallapaty, 2022). The August 2022 Pakistan flood caused more than 1,500 causalities (including 552 children) (United Nations, 2022) (see Figure 2). About one-third of the country was affected by floods and many communities suffered and urgently required emergency support by food, shelter and medical care. The coastal regions in South Asia such as the coast of the Indian Ocean, Arabian Gulf and Bay of Bengal often experience frequent Asian Monsoon disturbances during the summer season (Meybeck, 2009).

Thus, confronted with great flood risk with ice-melted scenarios from the connected catchments with the glaciers in addition to the frequent low-pressure S Asian Monsoonal Climatic effects with the coastal low-pressure moist rain belt during the late Spring and summer seasons (Meybeck, 2009; Wu et al., 2022). Due to rapid urbanization and extensive developments in the low-lying coastal floodplain areas (Rentschler et al., 2022), the single or compound flood risk that combines with coastal, pluvial and fluvial floods is increasing, and unlikely to be halted in the upcoming future under climatic extremes and uncertainties in S Asia (Varis et al., 2012). Severe and large floods in Pakistan have occurred occasionally such as the 2010 flood that caused over 1600 casualties, but the responses were not effective as the flood destroyed the main infrastructure (e.g. roads and bridges) and only relied on helicopters to slow relief efforts and caused severe impacts and the source of the flood is similar by intensive rainfall for these two floods (Larkin, 2010). The drivers of flood risk in Pakistan are significantly related to human-induced drivers such as high population growth, rapid land use changes (e.g. extensive deforestation), and increased runoff and peak discharge.

Indeed, the Pakistani Government established some response strategies after the 2010 flood and realised the importance of building flood infrastructure such as building dams at the upper and middle part of the Indus River, but these flood defences were not sufficient for southern Pakistan's communities and settlements. The Pakistani National Government realised the core values of improving flood resilience through technologies, such as improving flood preparations and responses by developing a more reliable flood forecasting system with the European Commission Joint Research Centre and testing a Global Flood Detection System to monitor floods (Rahman et al., 2016).

Figure 2 Pakistan floods in 2022 and the flood water flooded Karachi and surrounding areas in the low-lying flood-prone areas (Source: photo approved to use by envirolink.org).

Tactlessly, the 2022 flood occurred that created huge impacts and Pakistan displaced more than 33 million people in this event, combined with the damage cost of over USD$10 billion. The Pakistan prime minister, Shahbaz Sharif vowed to improve the relief measures to uptake the flood relief and vulnerability urgently required (Clarke et al., 2022). This flood, reflected the responses to emergency relief, especially on the financial aid and emergency post-disaster fundraising for flood relief efficiency to receive over Rs. 500 crores (US$2.5 million) in 3 hours. Among the Global Climate Risk Index, Pakistan ranked among other S Asian Nations – India, Bangladesh and Nepal all in the top 20 countries that have been affected by climatic extreme events and are the most vulnerable globally (Eckstein et al., 2018). Whist, the Pakistani National Government realised the phenomenon and lessons are similar to the 2010 flood, in which the non-structural risk reduction measures (e.g. flood warning and information communication systems) are insufficient, thus that affects the flood preparation and responses to deflect the flood resilience again reflected from the latest 2022 big flood in Pakistan (Kelman, 2022; Desk, 2022).

Across the border, India is one of the countries also severely affected by floods in S Asia, about 12% of India's territory is exposed to various floods, and the country is currently topped floods related casualties in Asia (Ashraf et al., 2017). Likewise, the rapid land use changes and urbanisation patterns have caused India to suffer urban pluvial or surface water floods because of inadequate drainage systems (Kadave et al., 2016). For example, the Kerala 2018 flood caused an estimated USD 4.4 billion economic loss. As a result, the event caused the deaths of over 430 people, destroyed about 17,000 homes and damaged an additional 217,000 (Hunt & Menon, 2020). Many studies have examined this flooding event and have linked it to various causes such as climate change (Hunt & Menon, 2020), changes in land use like deforestation (Paul et al., 2018), mining (Padma, 2018), and poor management of water reservoirs (Mishra et al., 2018 In response, the Indian Government has adopted flood forecasting, disaster preparedness (preparation), and flood zone identification, which integrates with the flood control via engineering and infrastructure (flood defence) (Abbas et al., 2015).

Also, the Kerala state government set up the Rebuild Kerala Initiative (RKI) to help rebuild and recover the state in the flood aftermath (https://rebuild.kerala.gov.in/rebuild-kerala-initiative/). It includes a diverse range of projects including the strategic roadmap for reconstruction across the state. Sayers et al. (2014) illustrated the importance of investing in flood preparation and response, especially in improving the flood forecasting, warning system, flood forecast and effective communication in all stages of a flood event (preparation, response and recovery stages). These practices keep alongside flood control by building various structures for flood control such as embankments, dykes and dams since the early 2000s (Gupta et al., 2003).

Looking forward, future climate change threats are increasingly threatening the country and South Asian neighbourhoods, especially coming from the flood source via melting Himalayan glaciers that create havoc for all South Asian communities that owned 25% of the world population within 3.5% of the global land use areas, plus the frequent summer South Asian Monsoons for intensive rainstorms (Haque et al., 2022).

2. Europe - German flood 2021

In 2021 July, there was an intensive rainstorm occurred in Western Germany with 60 – 180mm/24hr that caused severe riverine-enhanced flash floods which means the rapid flood occurred by the peak discharge and runoff from the hilly and mountainous area in the Ahr River catchment that flushed down to Ahr Valley, such as Koblenz and surrounding areas close to Bonn (the ex-capital city of West Germany) (see Figure 3).

Figure 3 German flood in July 2021 from the Rhine River sub-bench in the Ahr Valley, the state of Rhineland-Palatinate. (Source: China Meteorological Authority (CMA) and approved to use)

The rainstorm was surprisingly destructive and caused significant consequences owing to the rapid discharge from the higher reach of the river across the Ahr river, west of Bonn that caused over 130 causalities that is the most disastrous natural disaster in the region (Deutschland.de, 2021). The event alarmed the problems of the efficiency and effectiveness of the current flood warning and responses system especially in tackling flash floods in Germany noted that the rainstorm was intensive as reached a 1-in-100 years return period according to the German Weather Service and the forecast has been released before the flood arrived. This flood has also hit western European neighbourhoods such as Belgium and the Netherlands.

For example, the Netherlands had zero casualties due to a well-equipped stormwater management system and better preparation practices, such as relocation and evacuation took place in time downstream of the Rhine River (Schmidt et al., 2021). The German Federal authorities concerned about the countries have already undertaken advanced technologies in flood warning and communication systems and underlined with the EU Flood Directive (Gersonius et al., 2011). As a result, there are still suffered flood damages, which reflected the importance of the "communication" and "understanding" of flood information with the communities in Ahr Valley areas and even the technology (i.e. ICT) has been in-placed. The level of warning, the ways of communication and the responses from the responsible authorities including the police, fire services, army and emergency responses have questioned the effectiveness and efficiency to respond from that event (Otieno et al., 2022), such as the urgency of alert and the relocation practices to the vulnerable communities were questioned (Jordans, 2021).

3. Global countries – Nigeria, Japan and elsewhere

Nigeria

The floods of September/October 2022 that swept through Nigeria are regarded as the worst in the history of the most populous country in Africa (Onukwue 2022). The flood affected 32 of the 36 states in the country - Nigeria is a federation of thirty-six states and one Federal Capital Territory. According to official data, this flood has affected over 2.5 million people, replaced over 1.3 million from their communities, destroyed over 121,000 houses, injured over 2,000 killed over 600 people and destroyed over 108,000 farmlands (about 70,566 hectares of farmland) (Asadu 2022; Oguntola 2022; Okojie 2022). It is believed that this is a conservative estimate because of limited flood reporting across Nigeria. The floods also affected critical national infrastructures such as energy, transport, hospital and telecommunications (Izuaka 2022; Vanguard 2022). This negates all the massive government infrastructure investments to boost economic activities, and employment and achieve the Sustainable Development Goals (SDGs). The flooding situation is likely to worsen in the next few decades, especially for many coastal cities such as the economic and commercial capital - Lagos and oil-producing cities such as Port-Harcourt, Yenagoa and Riverine communities such as Lokoja and Makurdi. These are centres of large populations and their region's economic and infrastructure nerve centres.

The floods experienced in Nigeria are both fluvial and pluvial floods. Climate change has increased the intensity and frequency of rainfall, making floods more likely across Nigeria. According to Alfieri et al (2017) return period of 100 years is projected to increase from 1 in 40 years at 1.5°C to 1 in 21 years at 4°C warming. The excessive rainfall due to climate change causes overflow of water levels in rivers, lakes and streams in Nigeria and neighbouring countries, especially Cameroon. It is believed that the flood in Nigeria is further worsened when excess water in the Lagdo Dam built upstream of the Benue River in neighbouring Cameroonis released. The excess water released from Lagdo Dam flows downstream into Nigeria, contributing to the increased volume of water already in the rivers, lakes and streams (especially the River Benue). This compound style of pluvial floods caused by climate change and fluvial floods due to excess water in rivers, lakes and stream further exacerbate flooding. These combined factors are responsible for the devastating flooding experienced by the riverine communities along the Niger and Benue Rivers. The situation is further compounded by 'disregard for laws and regulations such as urban and regional planning laws', 'indiscriminate dumping of refuse, which often blocked drains and other water channels' and 'construction on drainage lines' (Adekola and Lamond). Urban growth (urbanisation, economic development and population growth) are also an issue. By 2050, Nigeria is projected to be the third most populated nation in the world after India and China and Lagos is the third most populous city with over 100 million people (United Nations 2017).

Despite the yearly flood experienced by Nigerian cities over the last decade and a 2012 flood with a scale similar to the 2022 flooding, Nigeria does not have a national flood management plan. After the recent flood, it was only a knee-jerk reaction that the National Emergency Flood

Preparedness and Response Plans were approved to mitigate and reduce the impact nationwide (The Guardian 2022). This underscores the Nigerian government's lack of proactive action and responses are often tainted by politics, 'flood control' 'through police power' such as demolition of buildings, and structural solutions. This is further compounded by the fact that governance of flood management cut across three tiers of government (local, state and federal), leading to fragmented and uncoordinated roles and responsibilities (Adekola et al 2020). Nature-based solution and adaptation to flooding is still relatively new and not actively promoted in Nigeria. This underscores the need for a policy shift from one dominated by a narrative that flood can be prevented to one that also prioritises anticipatory actions. The lack of proactive long-term planning to mitigate and adapt to the impacts of flooding is a problem. This will require a combination of structural, institutional and societal approaches. For example, structural solutions should include proactive engineered plans to redirect rivers which are prone to overflowing their banks and ecosystem-based approaches such as protecting and re-establishing wetlands. In addition, there is a need for flood management plans across the three tiers of government.

Japan

The Japan floods in 2018 July has caused at least 200 causalities as the heavy rainstorm downpours in SW Japan caused severe flash floods and caused more than 75,000 residents relocation and deployed to safer areas from the rescue operations in the W and SW Japan such as Saga, Fukuoka, Hiroshima, Okayama, Hyogo, Kyoto regions, as reported in the Sukumo City, Kochi. For example, it recorded about 263mm rainfall/2hr and at this range of rainfall for 2hr reached an equivalence of 1.5 times the average monthly rainfall in July (Ogura and Berlinger, 2018). The rainstorms caused by the typhoon "Prapiroon" with the summer seasonal rainfall also tracked the risk of landslides and authorities across the prefectures have alerted 2 million people to evacuate homes (see Figure 4). This flood was reported in the flood communities and victims suffered from water-borne diseases in the post-flood scenarios in Hiroshima, such as suffered fractures and skin lacerations but also had gastrointestinal infections due to the uptake of contaminated water sources under the flood condition (Fan and Huang, 2020).

In such hectic hazardous conditions with compound effects on flash floods and landslides or flash floods with accumulated acute sediments in Japan, the Japanese authorities have been quite well-prepared. The authorities have established a public-free and transparent flood hazard map based on the information provided by the Japan Central Government and offloading to cities, towns and villages. Thus, the communities can access freely to understand the location of dykes/flood walls/embankments and flood protection infrastructure; the potential flood risk areas, and the evacuation and emergency relocation or rescue routes and surviving locations (e.g. shelters and safety locations). For example, in Setagaya-ku, Tokyo, Japan and locate with temporary shelters in some schools the victims can use these emergency services for a short-term period to get the recovery and safe water, food and energy supplies to survive (see Figure 5). This information is vital as currently more than 50% of the Japanese population and 75% of properties are located in flood-prone areas in Japan (Fujita and Hamaguchi, 2012). Fan and Huang (2020) illustrated that the Japanese have experienced frequent natural hazards that alert them to be more sensitive in getting flood hazard information (i.e. flood warnings, meteorological conditions – rainfall, storm surges, and tsunamis). The country is equipped with advanced high technology of information transmission with popular mobile communication services via the internet, mobile phones, related apps and the local media system (online and ordinary TV and radio services (Chan et al., 2022b; Mori et al., 2022; Yamada et al., 2011).

Figure 4 Heavy spots of rain caused severe floods in Kurashiki, Okayama prefecture and Hiroshima, Japan on July 8, 2018. (Source: Clamorworld: approved to use the photo)

Other lessons

Other than Japan, there are also some other countries such as in E Australia (Greater Sydney, NSW), the United Kingdom (Yorkshire), Birmingham, Alabama, and the United States that have occurred severe floods all of them were similarly inundated by severe and intensive rainstorms and heavy downpours in the last few years (see Table 1 & Figure 6). Typically, these cases have the common lessons on “flood responses and preparations” that is well-using technology and especially for enhancing the communications such as “flood hazards map”, “flood warning”, “flood information communications” and “social media services”. Emergency responses, information transmission and communications are key to reducing the flood consequences on casualties, injuries and economic losses (enhanced early preparation).

The case of Pakistan in 2022 and especially in Germany in 2021 flood illustrates the lack of available flood warning system (in Pakistan’s case) and sufficient community communications (in Germany’s case) (Cornwall, 2021). Even though German is provided with the standard flood maps of the EU Flood Directive in the Rhine Valley region of western Germany, flood warning and information communication to communities is inadequate and immediate in the Koblenz and Aar valleys (Dietze and Ozturk, 2021).

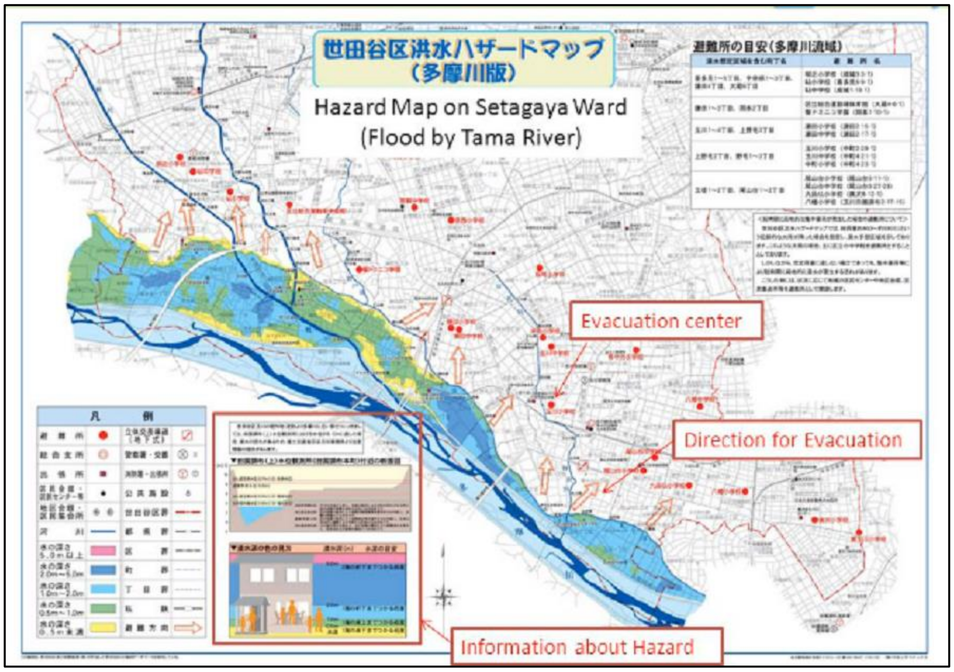

Figure 5 Flood hazard map in Setagaya-ku, Tokyo, Japan (Copyright © Setagaya-Ward, Municipal Govt. Tokyo – approved to use)

Table 1 Global major flood events and responses in the last 5 years

Date	Country and city	Maximum rainfall	Personnel casualties	Property damage	Response	Citation
2022/ 2/23	United Kingdom York	Total of 58mm for 12 hours	0	400 properties flooded	➢ The Government established flood response practices for temporary flood protection. ➢ UK Power Networks makes additional goodwill payments to those most affected by power cuts.	Brown et al. (2022); JBA Risk Management (2022)
2021/ 11/6	The United States Birmingham, Alabama	100-130mm per hour	4	250 families damaged	➢ The impact of the flooding event was recorded, including the number and location of properties affected. ➢ The relevant department assessed any problems with the drainage system.	AP news (2021); Birmingham Gov (2021)
2022/ 8	Pakistan	388.7mm	1,300	More than 1.7 million homes were destroyed and flooding caused US$40 billion worth of damage	➢ A telephone fundraising campaign to raise funds for flood victims and received 5 billion Pakistani rupees (or $22.5 million) in flood relief. ➢ Structural measures dominate flood risk management in Pakistan.	Kelman (2022); Desk (2022)
2022/ 4/7	Eastern Australia	>400 mm	22	A$1.5 billion	➢ Inform the community about the status of the flood through broadcast media, social media, door-knocking, text messages, online websites and emergency alarms. ➢ Individuals seek emergency support from government and community evacuation centres.	ABC News (2022); New South Wales Government (2022)
2018/ 8/1-2018/ 8/19	India, Kerala	758.6 mm (164% higher than normal)	>433	US$ 4.4 billion	➢ Launched Rebuild Kerala Initiative to help raise funds for reconstruction and rebuilding destroyed properties of people. ➢ National Disaster Response Force, Army, Navy and Air Force were deployed to provide rescue and relief support.	Government of India (2018)

2018/ 7/15	Japan	>400mm	225	US$9.86 billion	➢ Provide emergency shelter. ➢ Establish and manage disaster relief volunteer centres. ➢ Coordinate and manage disaster volunteer groups. ➢ Support for residents of temporary housing.	Bandaru *et al.* (2020); Peace Boat Disaster Relief (2018)
2022/ 10/9	Nigeria		>600	2.5 million people, displaced Over 121,000 houses destroyed Over 108,000 farmlands destroyed	➢ The Nigerian Government has set up a Presidential Committee for the Development of a Comprehensive Plan of Action for the Prevention of Flood Disasters in the country. The Committee is expected to present the Comprehensive Plan of Action for Preventing Flood Disasters in Nigeria within 90 days to the President. ➢ State governments with the help of the International Organization for Migration (IOM) provided emergency shelter and other assistance. ➢ The Federal Government through National Emergency Management Agency (NEMA) provided relief materials.	Bamigboye (2022); Shehu (2022)

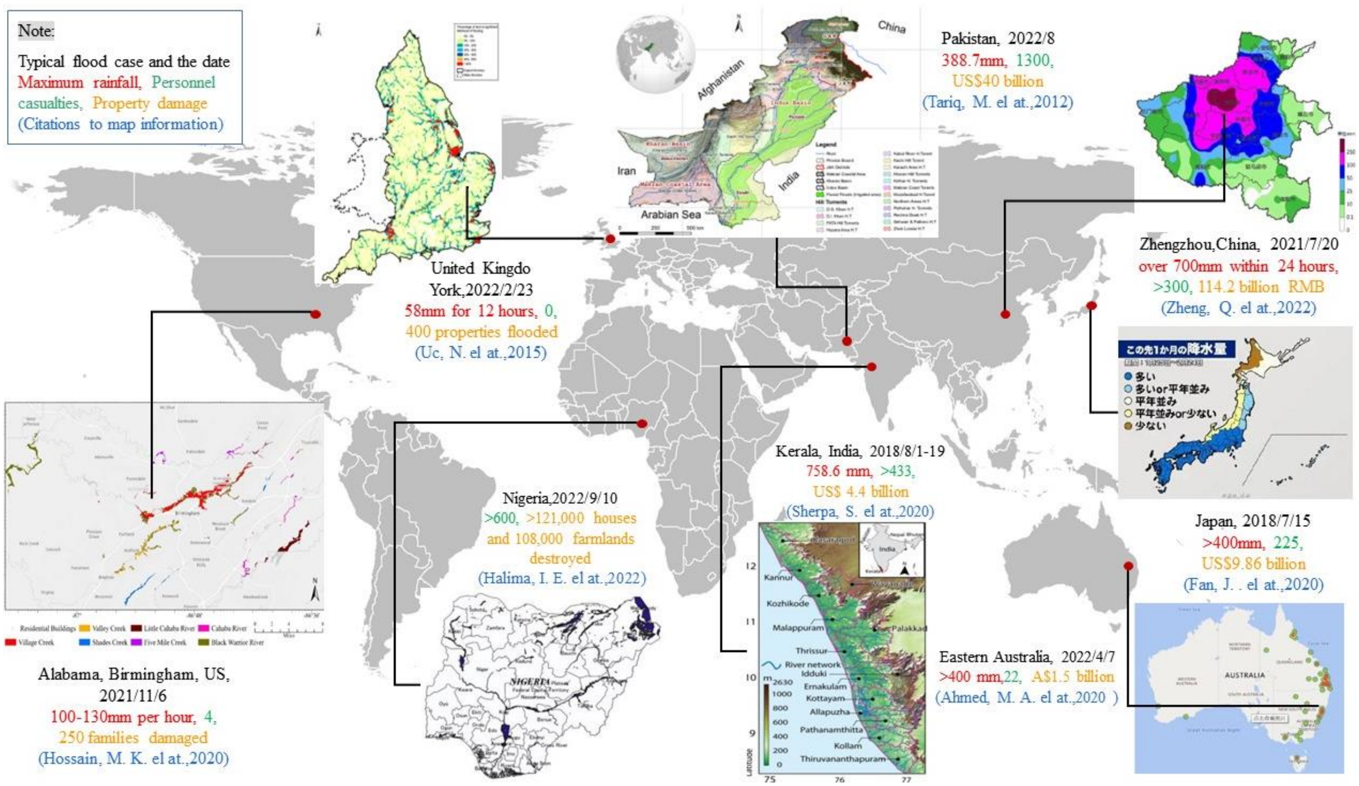

Figure 6 Recent Global flood impacts and hazards. Source: (Jiannan Chen, Zilin Wang and Xiaohui Lu)

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Discussion - Implications to Chinese cities

Adaptations and responses

Understood through these global (recent) lessons that the most impactful floods normally occurred by riverine (fluvial) flood, flash (hilly/mountainous) or compound floods also with Pluvial (surface water) flood and riverine combined flood, and storm surged-enhanced floods in low-lying areas (valley, river floodplains, coastal flood plains). These areas are the most densely populated, which is similar to China/Chinese cities (inland and coastal with rivers and coasts and deltas). That said normally these Chinese cities are exposed to flood risk with higher potentials, according to recent evidence such as the Zhengzhou flood (2021) (Chan et al., 2022a), Wuhan flood (2016,2020) (Wang et al., 2021) and GBA cities (i.e. Guangzhou, Shenzhen, Hong Kong SAR) coastal floods (2017, 2018, 2021) (Chan et al., 2021a; Lu et al., 2022).

Nevertheless, these cities have significant populations with approximately 8 or larger than 8 million megacities level, which translates these (mega)cities hotspots, as large populations are exposed to these flood sources (rainstorms, storm surges, SLR, etc.). However, some Chinese coastal cities are also exposed to tropical cyclones and monsoon effects in the summer. The Chinese inland and coastal megacities such as Setagaya-Ku and Tokyo can take Japanese cities as a lesson. This case with similar or even higher densely populated conditions (Tokyo currently with 37 million population)(Nakamura et al., 2020) as illustrated the best use of flood risk and hazard mapping system (for improving the flood preparations and responses) and the community responses practices and support (e.g. emergency rescue and post-flood emergency aid). The communities also have good traditions of proactively helping each other through community-based volunteered flood and other natural hazards activities, such as organising the flood patrol team to help with rescue and relocation practices and trails (Sakurai et al., 2011).

Whilst, these global lessons from Tokyo (Japan), Koblenz (Germany) and elsewhere are well-equipped and co-produced with the rescued and emergency services (and related institutions/departments/bureaus) are well reducing the flood impacts, consequences and risks for improving flood resilience. Similar practices have been found effectively successful in Chinese cities, for example during the Typhoon In-Fa in Ningbo, E Coast China, volunteered communities serve flood victims in temporary shelters by providing clean water and hot food (Chan et al., 2021b). Another example is in Tai O town Hong Kong where during the typhoons Hato and Mangkhut in 2017 and 2018, the communities co-produced the rescue services with the emergency authorities, such as Hong Kong Fire Services, Police Force, Civil Service Team and the Hospital Authority. The plan was used to conduct emergency relocation and rescue services for the coastal communities in Tai O town, New Territories in Hong Kong to get considerable success in saving lives and reducing flood risk (i.e. lowering the damages and injuries on coastal surges floods) (Chan et al., 2021a; Chan et al., 2018).

Information communication technologies are placed

Flood responses (and recovery), the core relationship for the affected flood communities, and the stakeholders (governmental agencies), aid organisations and the private sectors. Information communication technologies (ICT) are useful to build on effective communication between these key actors, such as using the technologies (social media, internet) to improve good communication, perception and understanding of flood and meteorological information to lead a better preparation, responses and recovery processes (Anil et al., 2019).

Effective communications also are the key to improving the emergency services such as rescue, relocation services, confirmation of the safety in the communities, etc., these operations are more effective via social media, the internet, and mobile technologies to deliver these operations (e.g. using Twitter, and social media texts streams in Australia's 2009 bushfires) that largely improve the disasters awareness information through these social media platforms, especially the technological feature on the geo-tagging technique is useful tracking the geographical locations and tagging with the flood locations. These services and technologies are helpful for governmental emergency services and communities for tracking real-time flood locations(Sakurai and Murayama, 2019).

These flood locations are important for the emergency services/authorities in the rescue of communities of flood victims. Information exchange on real-time flood conditions, transport and relief supplies availability and operational services are essential before enhancing more precise, accurate and effective decision-making processes for emergency relief and response. For example, improving the situational awareness of floods and surrounding communities, as flood victims can report on their surroundings via social media (Yin et al., 2012).

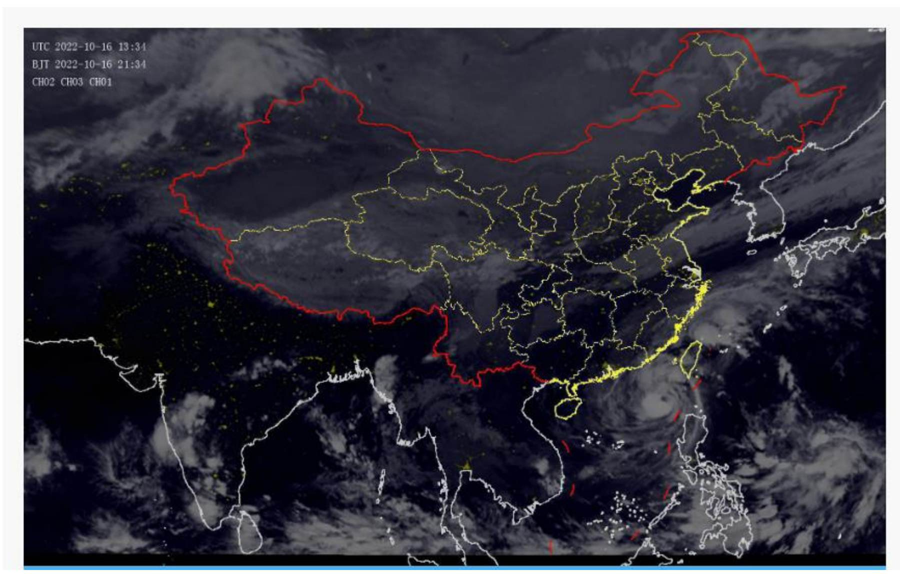

Figure 7 Satellite image provided by the China Meteorological Administration (CMA) that is opened to the public (Source: CMA approved to use)

Lessons – implications to the Chinese cities

In China, the National Emergency service is working closely with China Meteorological Administration (CMA) and initiating a free and transparent online service, for example, the public is free to track the typhoon (as shown in Figure 6 for the typhoon "Ni-Sha" is heading towards to S China Sea and Hainan Island) on 16 October 2022. Nevertheless, ICT includes social media and technologies (e.g. Smart Technologies, big data analytics, etc.) nowadays becoming vitally significant that fully recognised by the Chinese National Governmental authorities (i.e. CMA)(Wang et al., 2020; Zhai et al., 2021).

For example, well-used flood warnings communicate effectively via 5G mobile networks and e-platform, also through artificial intelligence services. The evidence Ningbo municipal government utilises social media services to update and report the road conditions via the online mapping service, and provided the real-time surface water flood (waterlogging) status to road users (drivers and pedestrians) during typhoons. The Ningbo municipal Government also adopted 3D mapping services to identify the inundated and suffered flood victims and affected communities to escape and relocate from flooded spots (e.g. Yuyao district)(Chan et al., 2021b; Griffiths et al., 2020). The Ningbo municipal Government expressed a big improvement in reducing flood impacts that adopting such technologies in flood preparation and responses compared to the typhoon Fitow in 2013, the estimated reduction of flood losses was more than 33 billion RMB (Chan et al., 2021b).

Indeed, these latest developed flood-resilient technologies are helpful in reducing casualties and injuries. For example, in the Zhengzhou flood in 2021, the municipal authorities could improve flood communications and preparations. Response practices such as halting the public transport system (i.e. underground services and all on-road public transport services) and giving more time for the public to return home earlier from work could potentially reduce the consequences (Chan et al., 2022a; Xiao, 2021). Meanwhile, in Hong Kong and the Greater Bay Area, information and communication technologies have a similar contribution to reducing flood damages and consequences. For example, the Hong Kong Observatory (govt. Met office) is using the mobile app and social media platforms (i.e. Facebook, WhatsApp, Instagram, Twitter, etc.) to update the latest meteorological warning and information (e.g. real-time precipitation, precipitation for last 24-72 hours (HKO, 2022), rainfall maps to show the amount of precipitation, wind speed and surge heights across all districts in Hong Kong) (Chan et al., 2021c; Chen et al., 2021). These practices demonstrated the success of using smart communication and technologies to achieve effective flood "response" and "preparation".

The ICT system helps Chinese communities, stakeholders, NGOs, and private investors (home landlords/owners) to record, exchange, and process flood disaster-related information all over in 4 disaster management stages with main caveats on flood risk reduction, improving preparedness, providing effective flood emergency responses, enhancing a better recovery process and achieving more resilient Chinese cities.

Immediate responders play a crucial role by performing lifesaving interventions in the immediate aftermath of a disaster. However, these people are usually not trained in disaster management. They are pushed into the disaster response just because they are presenting in the disaster zone. During the Kerala floods of 2018, the local fishermen were the immediate responders of the flood before authorities and rescue workers could reach them. Although limited physical and financial resources set them back, they utilized their social abilities effectively and saved more than 65000 people. This example suggests possible measures to improve community resilience during emergencies. Government interventions can further improve community resilience. For instance, by providing at least basic disaster response training and education in the communities in frequent disaster-hit areas to improve their resilience. The lesson that can be learned from the response to the Kerala floods of 2018 is making vulnerable communities into resilient communities.

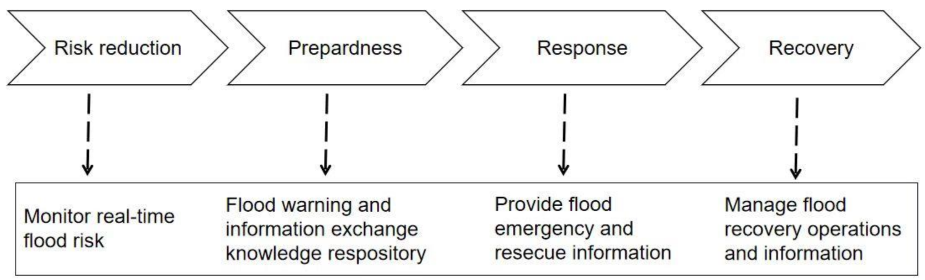

Figure 8 Role of ICT in flood disaster management process (adopted from Sakurai and Murayama (2019))

Conclusion

Flood hazards are natural and inevitable, but we can reduce flood impacts by improving flood resilience. The modern world gives us opportunities on implementing strategies for flood preparedness and responses with technologies (i.e. ICT) on soft flood protection measures. Of course, if there are enough time and financial capacities, the best will also improve the "hard" (engineering) flood protection infrastructure altogether.

This review reflected the major global floods in the past five years across 3 continents, and it seems that from the experiences from Pakistan, Germany, Japan and Nigeria and elsewhere, there were a few valuable lessons obtainable. The climate extremes (i.e. extreme rainstorms and storm surges) occurred more frequently, plus the climate change effects (ice-melting, SLRs) with El-Nino and La-Nina effects, which resulted in increased exposure by coastal, riverine, pluvial or compound flood with any combinations of these flood types. That causes the communities to be more vulnerable. The Sendai and United Nations disaster reduction framework provides the scope and pathway for improving future flood and climate resilience.

Through the recent global flood lessons (good or bad), preparedness and responses are the major keys to reducing flood impacts. In particular for flood preparedness, mobile phone apps, online news and radio channels combined with social media platforms (e.g. Facebook, Twitter, Weibo, WeChat, WhatsApp, etc.) improve the effective communication on flood warnings and preparation information. Moreover, the ICT, smart technologies and communications are also effectively providing important related information via geo-tagged/tracked emergency services for the rescue, relocations and displacements on the responses, for example, the Chinese cases in Ningbo and the Greater Bay Area with success on reducing flood impacts, which will be the future cornerstone of flood disaster reduction management practices.

Conflict of Interest

On behalf of all co-authors, there is no conflict of interest in this manuscript.

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Author contributions

All authors contributed to the study design and the manuscript. All authors read and approved the final manuscript. FKSC contributed as the first author, developing the idea and writing the first draft of the manuscript. XL, WZL & JW contributed to the general design of the study and the manuscript and joined FKSC as joint correspondence authors. JC, WZL and XL contributed to the graphics and diagrams. Other all co-authors – JC, WZL, OA, JGH, TN, PL and JW – contributed to the review of and edits to the concept, theory, and storyline (including the discussion and conclusion) of this manuscript.

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