Received: 31 January 2020 | Revised: 15 October 2020 | Accepted: 16 December 2020

DOI: 10.1111/jfr3.12689

ORIGINAL ARTICLE

CIWEM Chartered Institution of Water and Environmental Management | Journal of Flood Risk Management | WILEY

Understanding and assessing flood risk in Vietnam: Current status, persisting gaps, and future directions

Minh Tu Nguyen[1] | Zita Sebesvari[1] | Maxime Souvignet[1,2] | Felix Bachofer[3] | Andreas Braun[4] | Matthias Garschagen[5] | Ulrike Schinkel[6] | Liang Emlyn Yang[5] | Linh Hoang Khanh Nguyen[8] | Volker Hochschild[4] | André Assmann[7] | Michael Hagenlocher[1]

[1]United Nations University—Institute for Environment and Human Security (UNU-EHS), Bonn, Germany

[2]Munich Climate Insurance Initiative (MCII), Bonn, Germany

[3]German Aerospace Center (DLR)—Earth Observation Center (EOC), Wessling, Germany

[4]University of Tübingen, Institute of Geography, Tübingen, Germany

[5]Department of Geography, Ludwig-Maximilians-University Munich (LMU), Munich, Germany

[6]IZES gGmbH, Saarbrucken, Germany

[7]Geomer GmbH, Heidelberg, Germany

[8]Hue University, International School, Thua Thien Hue, Vietnam

Correspondence

Minh Tu Nguyen, United Nations University—Institute for Environment and Human Security (UNU-EHS), UN Campus, Platz der Vereinten Nationen 1, 53113 Bonn, Germany.
Email: nguyentudhct@gmail.com

Funding information

Bundesministerium für Bildung und Forschung, Grant/Award Number: 01LE1905G

Abstract

Vietnam is exposed to different types of floods that cause severe economic losses, damage to infrastructure, and loss of life. Reliable information on the drivers, patterns and dynamics of flood risk is crucial for the identification, prioritization and planning of risk reduction and adaptation measures. Here, we present a systematic review of existing flood risk assessments in Vietnam. We evaluate the current status, persisting gaps, and challenges regarding the understanding and assessment of flood risk in the country. The literature review revealed that: (i) 65 % of the reviewed papers did not provide a clear definition of flood risk, (ii) assessments had a tendency to prioritize physical and environmental drivers of risk over social, economic or governance-related drivers, (iii) future-oriented assessments tended to focus on hazard and exposure trends, while vulnerability scenarios were often lacking, (iv) large and middle-sized cities were assessed more frequently than others, (v) only few studies engaged with relevant local stakeholders for the assessment of risk and the development of potential solutions, and (vi) ecosystem-based adaptation and flood risk insurance solutions were rarely considered. Based on these findings, we point out several directions for future research on flood risk in Vietnam.

KEYWORDS

disaster risk reduction, integrated flood risk management, risk assessment, vulnerability

1 | INTRODUCTION

Globally, nearly 70 million people are exposed to flood risk each year (UNDRR, 2011). A recent global assessment of river flood vulnerability in the last 50 years revealed both decreasing and increasing trends in river flood risk, indicating a spatial distribution of flood hazards, exposure and vulnerability among different geographies (Tanoue, Hirabayashi, & Ikeuchi, 2016). The most recent report of the Intergovernmental Panel on Climate Change (IPCC) concludes with very high confidence that 'risk related to sea-level rise (including erosion, flooding and salinization) is expected to significantly increase by the end of this century along all low-lying coasts in the absence of major additional adaptation efforts' (IPCC, 2019, p 56). While the link between climate change and flooding was still weakly established in 2014 when the fifth Assessment Report of the IPCC was published (IPCC, 2014), recent climate models have revealed that future changes in rainfall patterns will lead to increasing flood risk worldwide, but notably in areas around big cities (Dottori et al., 2018; Willner, Otto, & Levermann, 2018). In addition, a recent study that used revised coastal elevation data found that the amount of people threatened by projected sea-level rise and coastal flooding in 2100 might be three times higher than previous estimates (Kulp & Strauss, 2019).

Flooding is not only a global concern, but also one of the main hazards in Vietnam that frequently causes severe economic losses and casualties (Luu, Meding, & Mojtahedi, 2019). The country has a long coastline of 3,200 km coupled with highly concentrated populations and economic assets located at river deltas and other low-lying areas, exposing these areas to multiple hazards such as sea-level rise (SLR), storm surges, typhoons, and flooding (Bangalore, Smith, & Veldkamp, 2017). It was estimated that as of 2010 about 930,000 people in the country are exposed to flood risk, with total annual losses to flooding of approximately 2.6 billion USD (World Bank, 2018). The country is also exposed to many different types of floods such as fluvial floods (river floods), flash floods, pluvial floods (surface flood occurring in urban areas) and coastal floods caused by tides, typhoons and storm surges. In the south of Vietnam, river flooding is most prevalent: driven by a slow rising and falling of water levels in the rivers, tidal influence, or sometimes a combination of both (An & Kumar, 2017; Triet, Viet Dung, Merz, & Apel, 2018). In Central Vietnam, river floods with high flow intensity and rapidly rising water levels following torrential rains can be disastrous (Casse, Milhøj, & Nguyen, 2015). The mountainous areas in the Northwest and Northeast of Vietnam are located in a tropical cyclone zone, exposing them to extreme rainfall events together with typhoons, which often leads to destructive flash floods as well as accompanying landslides (Tien et al., 2019; Tien, Tsangaratos, Thao, Dat, & Thai, 2019). With the acceleration of urbanisation since Doi Moi (social, economic, and political renovation starting in 1986), flood risk has increased in urban areas (Huong & Pathirana, 2013). This trend is aggravated by population growth, economic development and the associated expansion of buildings and infrastructure into flood-prone areas (Huong & Pathirana, 2013; Storch & Downes, 2011; Sudmeier-Rieux et al., 2015). During the period 2012–2015, several major floods occurred in Vietnamese cities, notably in Hanoi, Quang Ninh, Da Nang, Can Tho, and Ho Chi Minh City (ISET, 2016). The combined effects of heavy rainfall, typhoons, tides and SLR are projected to lead to a greater flood risk in urban areas in Vietnam (ISET, 2016).

The traditional perspective on flood hazard assessment considers floods as purely natural phenomena while the role of flood management is to reduce the probability and consequences of the event (Merz et al., 2014). This hazard-focused view of flooding is strongly based on the hydrologic/hydraulic characteristics of the river systems and basins (Merz et al., 2014). Today, it is well recognised that flood risk is characterised by both natural and societal elements rather than solely the former (IPCC, 2014). There have been several risk and vulnerability definitions developed over the last decades. The definition of risk as a combination of hazard and vulnerability was initially recognised by Blaikie, Cannon, Davis, and Wisner (1994), who defined risk as a product of both hazards as well as the political and socio-economic conditions that make people or places vulnerable. This approach has since been widely adopted by several scholars (Birkmann, 2006; Birkmann et al., 2013; Turner II et al., 2003, among others). The IPCC SREX report in 2012 defined risk as a function of the hazard (composed of probability, intensity, duration and extent), the systems or population exposed to the hazard, and the vulnerability of these systems, including concepts such as susceptibility, sensitivity to harm, and the lack of capacity to cope (IPCC, 2012). The vulnerability and risk perspectives underscore the linkages between hazards and society and usually involve the consideration of the root causes and spatio-temporal dynamics of risk (Jurgilevich, Räsänen, Groundstroem, & Juhola, 2017). In the literature, there is also a call for exploring the root causes of changes in all risk elements for better flood risk projection and management (Binh, Umamahesh, & Rathnam, 2019; Merz et al., 2014). Especially in urban contexts, the risk-based perspective is vital for urban water management as the intersection of natural processes with various social-economic activities amplifies flood risk, which requires a comprehensive assessment of various sectors (including underground infrastructures) and risk aspects (Habitat III, 2017; Lyu, Shen, Zhou, & Yang, 2019).

Currently, both hazard and vulnerability or risk-based approaches have been applied in flood risk assessments in Vietnam, and a variety of methods have been applied spanning these perspectives. Despite the heavy losses and damage caused by floods, information and data on the development of solutions to flood risk reduction and adaptation remain insufficient (Chinh, Bubeck, Dung, & Kreibich, 2016). The lack of effective solutions in Vietnam is partly hampered by institutional factors, for example, challenges in the implementation of decentralisation of flood risk management due to local capacities and resources (Garschagen, 2016; Huynh & Stringer, 2018), or a lack of stakeholder participation in the planning and implementation of potential risk reduction and adaptation options (Huu, 2011). In addition, a synthesis of existing information on flood risk patterns and root causes or drivers of flood risks across various contexts in Vietnam has not been undertaken so far. However, flood risk management is currently one of the main objectives highlighted in national-level policies, such as the National Strategy for Natural Disaster Prevention, Response, Mitigation until 2020 (GoV, 2007), the National Target Program to Respond to Climate Change (GoV, 2008), the National Climate Change Strategy (GoV, 2011) and the National Action Plan on Climate Change (GoV, 2012a), as well as the Law on Natural Disaster Prevention and Control (GoV, 2013), among others. Furthermore, province-level authorities are also obligated to develop and implement local action plans to respond to climate change (GoV, 2008). Accordingly, information on risk assessment and management, as well as drivers and solutions to flood risks, is vital to inform flood risk reduction and adaptation planning in the country.

Against this background, we conducted a systematic search, review, and synthesis of the scientific literature on flood risk assessments carried out in Vietnam. We explored the main methodological approaches and persisting gaps to provide insights into future directions for flood risk research and implications for improved flood risk management in the country. The paper identifies which concepts and approaches are being applied in flood risk assessment in Vietnam, and how respective discrepancies, for example rural and urban contexts, influence assessment approaches and outcomes. The results of the review also provide useful information for flood risk management and adaptation, especially on the drivers of flood risks in Vietnam and the potential role of ecosystem-based solutions.

TABLE 1 Search terms, inclusion and exclusion criteria used to identify studies to be considered for this review

Database	Search terms
Web of science (topic)	TS = (flood Vietnam) AND TS = (risk OR vulnerab* OR resil* OR suscept* OR sensitiv* OR expos* OR cop* OR adapt*)
Scopus (article title, abstract, keywords)	Flood Vietnam AND (risk OR vulnerab* OR resil* OR suscept* OR sensitiv* OR expos* OR cop* OR adapt*)
Inclusion criteria	• Peer-reviewed articles from January 1950 to September 2019 • English literature • Articles presenting risk analyses or part of it such as flood vulnerability and exposure analysis, either with a single hazard approach or together with other events (e.g., drought, storms). • Articles presenting all types of flood (flash flood, fluvial flood, coastal flood, pluvial flood) • Articles analysing flood risk and developing flood models to cover both drivers of vulnerability to flooding and drivers of flood occurrence/exposure
Exclusion criteria	• Review articles, opinion pieces, non-peer reviewed literature • Articles not in English • Papers that solely mentioned risks related to flood events (e.g., health issues during a flood, or water contamination due to flooding) without presenting an assessment of risk

2 | METHODOLOGY

2.1 | Systematic literature review

Our analyses are based on a systematic search and review of scientific articles on flood risk assessment in Vietnam listed in SCOPUS and WOS (Web of Science) since 1950. After an initial search to explore the variability and depth of the research topic, we constructed a set of search terms in order to cover as many papers about flood risk assessments in the country as possible. The first part of the search terms covered the main research topic 'flood' and the geographical location 'Vietnam'. The second part of the search terms contained combinations of 'assessment words', such as 'risk, vulnerab*, resil*', and so forth, to specifically capture studies on flood vulnerability and risk assessment (Table 1).

After the definition and construction of the search terms and criteria, the search for relevant papers in SCOPUS and WOS was conducted in September 2019. The abstracts were subsequently screened to identify the relevant papers on the research topic (Table 2).

TABLE 2 Search results in SCOPUS and Web of Science (WOS)

	SCOPUS	WOS	Total
Searched result	263	256	519
Dropped	2 (repeat)	153 (overlap with SCOPUS)	155
Abstracts reviewed	261	103	364

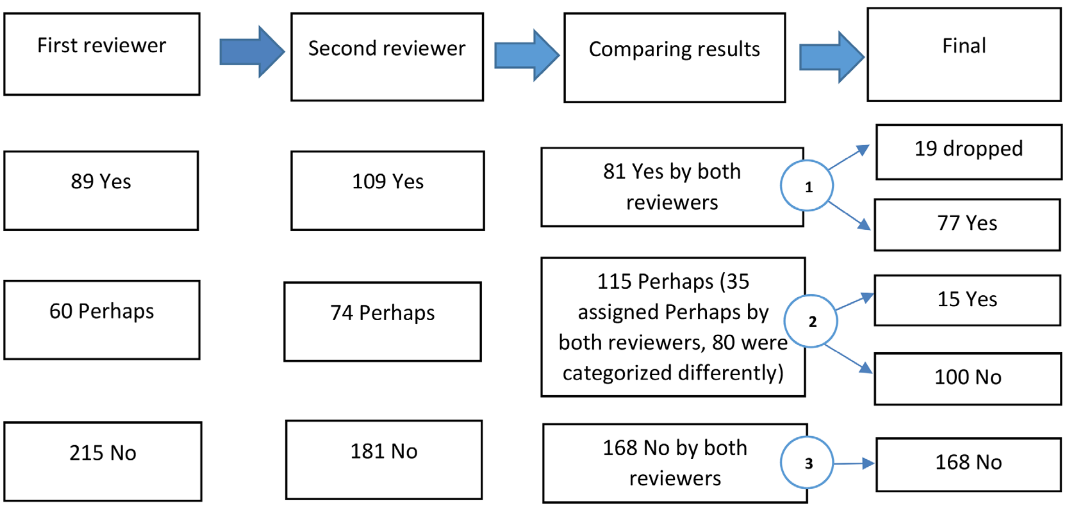

FIGURE 1 Process and results of the abstract screening. 1. Of 81 papers, 19 papers dropped as review papers, book chapters, conference papers, papers in other languages (15 papers), or considered irrelevant during the coding process (four papers). 2. Of 115 papers, 80 papers that were categorised differently were checked by a third reviewer. The whole 115 papers were screened for the final decision. Fifteen papers were considered relevant and assigned as 'Yes'. Others were excluded and assigned as 'No'. 3: No check

First, two researchers screened the obtained abstracts independently. Each abstract was either assigned 'Yes' if the paper is relevant, 'No' if not, and 'Perhaps' if the decision could not be made based on the abstract alone (according to the inclusion and exclusion criteria in Table 1). If the paper was categorised differently by the two researchers, it was passed to a third reviewer. In controversial cases, the final decision was made by the first author after reading through the whole paper (Figure 1).

2.2 | Guiding questions and content analysis

Full papers in the 'Yes' list were downloaded, and an in-depth content analysis was carried out with the software program MAXQDA (VERBI, Berlin, Germany). The software is a tool for qualitative/mixed-method analysis, in which the text parts of interest have been coded to determine for example the frequency of certain measures, topics, and so forth. All relevant papers were imported into the software program for data management and text analysis. Coding and content analysis was based on the following set of guiding questions:

1. How is flood risk conceptualised in studies in Vietnam?
2. Which approaches, methods, and tools are used to assess vulnerability and flood risk in Vietnam? To what extent are Vietnamese authors and stakeholders involved in the assessment process?
3. What is the spatial distribution of existing studies among urban and rural settings, hinterland (landlocked areas that are located far away from the coast) and coastal areas, and among the eight officially classified geographical regions of Vietnam?
4. What are the main drivers of vulnerability and risk to flooding in Vietnam, and how are they classified/characterised? Are there commonalities and differences regarding the drivers of flood risk in urban and rural areas? What are the most relevant drivers of risk?
5. Are spatial and/or temporal dimensions of vulnerability and risk to flooding considered/assessed? If so, at what scale? To what extent are scenarios of future flood risk used? If so, which risk components (hazard, exposure, vulnerability, or all combined) feature in these scenarios?
6. Which units/elements at risk (people, buildings or infrastructure, agricultural land, etc.) are considered in existing risk assessments?

7. Do existing assessments provide recommendations for flood risk reduction and adaptation? If so, which measures or solutions are suggested?
8. To what extent are ecosystems and ecosystem services considered as drivers of flood vulnerability and risk? Are ecosystem-based measures considered as part of the solution for flood risk reduction (EcoDRR) and adaptation (EbA)?

Following different risk definitions in the introduction section, we classified the risk definition in the reviewed papers as follows:

1. Risk as a combination of hazard and vulnerability (risk = hazard x vulnerability, for example, Blaikie et al. (1994))
2. Vulnerability as a combination of hazard, exposure, and resilience or adaptive capacity (vulnerability = hazard x exposure x resilience/adaptive capacity, for example, IPCC [2007])
3. Risk as a result of interaction between hazard, exposure, and vulnerability (e.g., IPCC, 2014)
4. No risk definition
5. Others (e.g., papers that provided their own risk definition).

In addition, we classified the reviewed papers into studies that focused on: (a) hazard, (b) exposure, (c) vulnerability, or (d) a combination of these risk elements, and then compared risk assessment perspectives across contexts to explore if different risk conceptualizations/perspectives influenced the proposed solutions and approaches, for example, the applied methods and assessment scales. We further compared the drivers of flood risk across different geographic locations in Vietnam, between rural and urban contexts, and between hinterland and coastal areas to identify the variations of drivers between different locations and contexts.

The coding was conducted by two researchers, whereby the first researcher (first author) developed the coding scheme in collaboration with the co-authors for the in-depth content analyses and coded the relevant publications (n = 77). The coding results were then cross-checked by a second researcher to reduce bias and errors.

3 | RESULTS AND DISCUSSION

3.1 | Main features of flood risk assessments

Almost all papers (97%) from the initial search were published after 1996, with the exception of two (1976 and 1989). All papers classified as relevant (n = 77) were published in 2007 or thereafter. Out of 77 papers reviewed, 47 assessments were first-authored by Vietnamese scientists (based on their first and last names). The remaining 30 papers were first-authored by foreign scientists, of which 13 papers (43%) were co-authored without Vietnamese scientists. Out of the reviewed papers, nine assessments (12%) engaged with local stakeholders in at least one stage of the assessment process. Of these, only two studies developed solutions to reduce flood risks in collaboration with relevant stakeholders (for a list of reviewed papers, see Appendix 1).

A large number of flood risk assessments were conducted in the Mekong Delta (n = 21, 27%) and at the South (n = 12, 16%) and North Central Coasts (n = 12, 16%) (Figure 2). These regions typically receive the highest precipitation (Figure 2) and rank the highest for flood risk in Vietnam (Luu et al., 2019). Other regions considered in the reviewed studies include the Southeast (n = 10, 13%), Northwest (n = 7, 9%), Red River Delta (n = 6, 8%), and Northeast (n = 2, 3%). The Central Highland is the only region in Vietnam not considered in any flood risk study so far. Several assessments (n = 7, 9%) targeted more than one region or were at the national scale.

A comparable number of papers conducted assessments in rural (n = 33, 43%) and urban contexts (n = 28, 36%). Other studies (n = 16, 21%) targeted the national and regional levels, comprising both rural and urban contexts, or no setting could be recognised (e.g., papers that developed and applied hydraulic models). In addition, most flood risk assessments in the urban context targeted large and mid-size cities (classified as category I or II by the Vietnamese government). Ho Chi Minh City is the most frequently analysed city (n = 10, 13%), followed by Can Tho (n = 9, 12%) and Hanoi (n = 4, 5%). Ho Chi Minh City is the largest metropolis in Vietnam and is considered one of the cities most impacted by flooding globally (Hallegatte, Green, Nicholls, & Corfee-Morlot, 2013). Can Tho City in the Mekong Delta is largely influenced by the floodwater from the Hau River and tides from the East Sea (Chinh, Dung, Gain, & Kreibich, 2017). The city has a low topography and does not have an adequate drainage system and flood protective structures, leading to urban flooding (Huong & Pathirana, 2013). In contrast to Ho Chi Minh City and Can Tho, Hanoi has a system of river dikes to protect the dense infrastructure and population. Therefore, most studies on flood risk in Hanoi focused on local inundation in urban areas due to heavy rainfall. Studies on river flooding mainly targeted the expanding area outside the dikes (Hung, Shaw, & Kobayashi, 2007). Table 3 summarises the main features of the reviewed papers and the

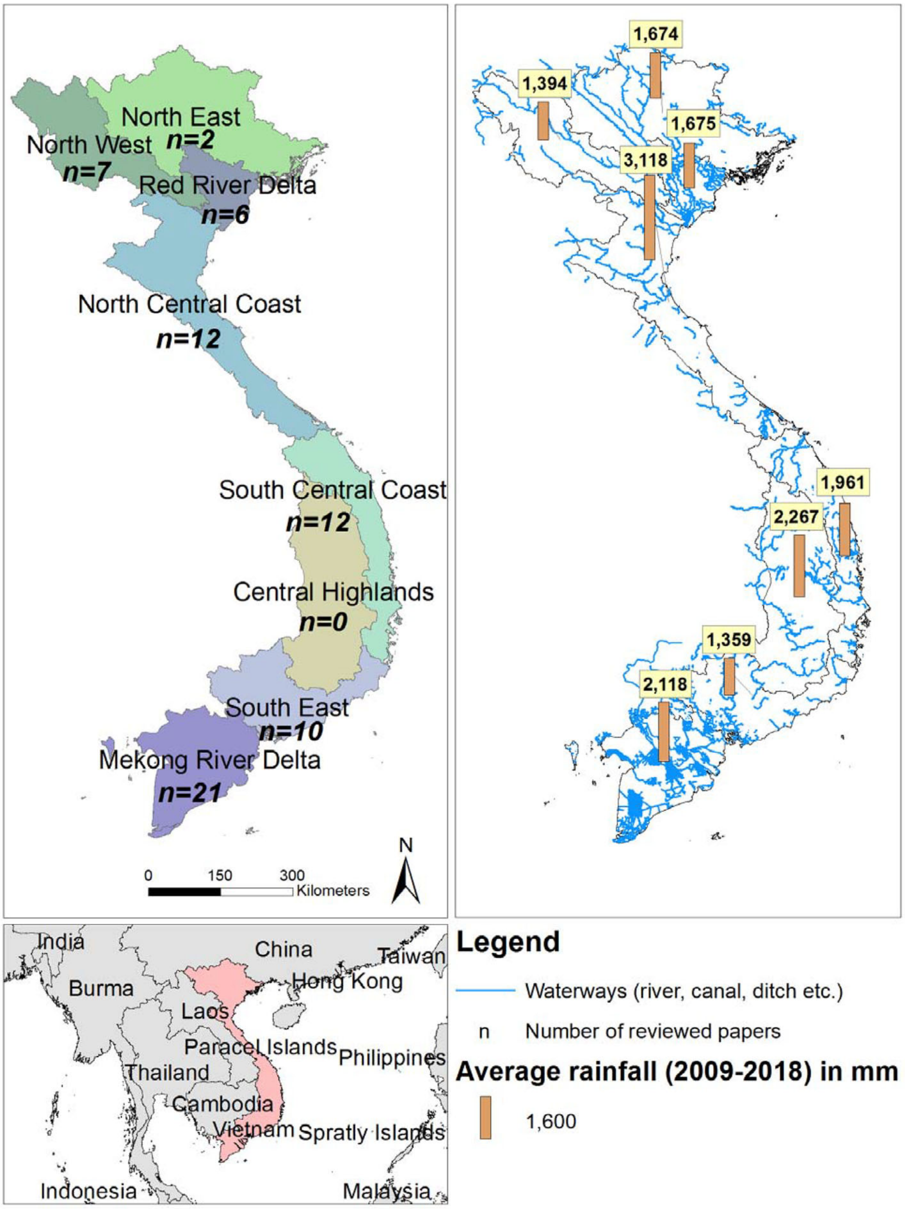

FIGURE 2 Map of different geographical regions of Vietnam with the number of reviewed papers and their natural characteristics (average rainfall during 2009–2018 and waterways; rainfall data from GSO, 2019)

flooding characteristics of the main geographical regions of Vietnam.

Thirty-six papers (47%) focused on the coastal provinces, while 25 papers (33%) conducted assessments in the hinterland, and 16 assessments (21%) conducted at national and regional scales included both hinterland and coastal settings. Accordingly, all papers carried out in the South and North Central Coast are classified as 'coast' since all provinces in these regions have a border with the sea, while the studies in mountainous areas of the Southeast and Southwest are classified as 'hinterland'. Most of the papers at the regional and national scales are classified as 'others' ($n = 16$, 21%), as they possess both hinterland and coastal characteristics.

The most common unit of analysis is an administrative area, for example, commune/ward, district or province ($n = 47$, 61%), in which the researchers analyse the vulnerability or flood risk of the entire area. Other units of analyses include ecosystems, for example, a river basin or floodplain area ($n = 18$, 23%), people or households, for example, health risk, people's perception, casualties ($n = 7$, 9%), infrastructure such as houses, roads or dikes ($n = 3$, 4%), and other units such as governance or policy systems in the context of flood risk management ($n = 2$, 3%).

3.2 | Conceptualization of flood risk

Out of 77 papers reviewed, the majority of studies ($n = 50$, 65%) did not define risk specifically, while 10 papers (13%) used their own definition of risk, for

TABLE 3 Number of reviewed papers and flooding characteristics in the main geographical regions of Vietnam

Geographical regions	Number of papers	Rural/urban/others	Flooding characteristics
Mekong Delta	21	4/9/8	Type of flood: Fluvial and pluvial Main rivers: Hau river, Tien river Tide influence: far inland with an amplitude between 3.5–4.0 m from the East Sea, and 0.8–1.2 m from the Gulf of Thailand (Tri, 2012; Tuan, Hoanh, Miller, & Sinh, 2007) Flooding characteristics: slow rising and receding of river water for 2–6 months, and rapidly between July and November (Chinh et al., 2016) Flood control measures: river dikes, drainage, floodwater discharge canals, and sluice gates (Hoang et al., 2018)
South Central Coast	12	7/3/2	Type of flood: Fluvial Main rivers: Tra Khuc river, Ve river, vu Gia river, Thu bon river, Da rang river Tide influence: diurnal tid range between 0.2–1.5 m, short reach of tidal influence (Huong, Quy, & Thanh, 2010) Flooding characteristics: short time of concentration, floodwaters rise rapidly, widespread flooding (Linh, Tri, Thai, & Cao Don, 2018) Flood control measures: river and sea dikes, several reservoirs (Nuoc Trong, Dak Drinh 1, Song Tranh 2, A Vuong, Dak Mi 4, etc.) for flow control (GoV, 2012a, 2012b)
North Central Coast	12	10/0/2	Type of flood: Fluvial and pluvial Main rivers: Huong river, Han river, lam river, Gianh river Tide influence: irregular diurnal tide between 1.2–2.5 m (Hanh and Furukawa, 2007) Flooding characteristics: water volume varies greatly year by year, water quantity during the flood season (October to December) constitutes 50–80% of the total annual volume (Villegas, 2004) Flood control measures: river dikes, estuarine and sea dikes, reservoirs (Cua Dat, Hua Na, Trung Son) and lagoon for flood control (GoV, 2012a, 2012b)
Southeast	10	0/10/0	Type of flood: Fluvial and pluvial Main rivers: Sai Gon river, Dong Nai river, Be river Tide influence: the whole area is influenced by an irregular semidiurnal tide range between 1.2–2.5 m (Hanh and Furukawa, 2007); the Sai Gon-Dong Nai basin is strongly affected by a daily tidal regime with high water level amplitude (Lee, Dang, & Tran, 2018) Flooding characteristics: large variation between seasons, water discharge during the flood season (mid-June to November) accounts for 70–80% of the annual volume (Lee et al., 2018) Flood control measures: River dikes, reservoirs (e.g., Tri An and Dau Tieng) for flow control
Northwest	7	7/0/0	Type of flood: Flash flood Main rivers: Da river, ma river, Thao river Tide influence: None Flooding characteristics: precipitation concentrated largely in the rainy season (November to April), flash floods occur together with landslides (Thao et al., 2018) Flood control measures: River dikes
Red River Delta	6	2/4/0	Type of flood: Fluvial, pluvial and flash floods Main river: Day river, Duong river, Thai Binh river, Ninh co river, Tra Ly river, Ba Lat river, Van Uc river Tide influence: varies between 0.5–2.5 m, tide influence reaches far inland (1 m of water level amplitude can be observed 120 km from the coast) (Minh et al., 2010)

(Continues)

TABLE 3 (Continued)

Geographical regions	Number of papers	Rural/urban/others	Flooding characteristics
			Flooding characteristics: water volume in the river varies largely between the dry and wet season (Hansson & Ekenberg, 2002); pluvial flooding in Hanoi is mainly caused by local rainfall with strong seasonal variation (Luo et al., 2018) Flood control measures: river and sea dikes, reservoirs (Hoa Binh, Son La, etc.) for flow control, pumping stations for water drainage, and sluice gates (Quang et al., 2019)
Northeast	2	1/0/1	Type of flood: Flash flood Main river: Chay river, lo river, gam river, Cau river, Thuong river, bang river, Bac Giang river, Ky Cung river Tide influence: None Flooding characteristics: flood waters rise rapidly, peak discharge after 1–2 days of torrential rains (JICA, 2003) Flood control measures: River dikes
National level or more than one region	7	1/2/4	Type of flood: Mainly fluvial or not specified

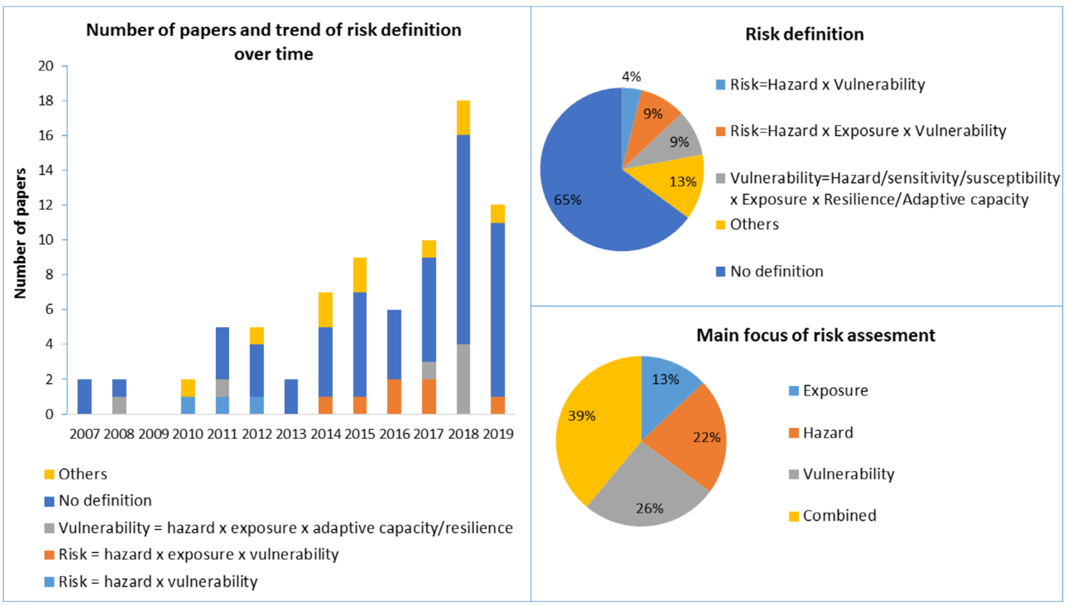

FIGURE 3 Conceptualization of flood risk in the reviewed publications ($n = 77$)

example, risk as a result of the probability and consequences. There were only seven papers (9%) that defined vulnerability as a combination of hazard, exposure, and resilience or adaptive capacity; seven papers (9%) defined risk as a result of interaction between hazard, exposure and vulnerability following the latest IPCC definitions; and three papers (4%) defined risk as an incorporation of hazard and vulnerability based on the risk concept of Blaikie et al. (1994). Similar to the findings of a recently published review of global drought risk assessments (Hagenlocher et al., 2019), the number of papers that applied the risk definition of the IPCC (in the SREX framework or its subsequent fifth Assessment Report) has increased since their publication in 2012 and 2014, respectively. However, there is also an increasing trend of papers that did not specify the risk definition for flood risk assessments (Figure 3).

Many papers ($n = 30$, 39%) focused on the analyses of multiple risk elements such as hazard and exposure, or hazard and vulnerability. Others only assessed vulnerability to floods ($n = 20$, 26%), flood hazards ($n = 17$, 22%), or exposure to flooding ($n = 10$, 13%). Several papers

(n = 5, 7%) that mentioned risk or vulnerability assessment in the title performed only hazard and exposure analyses without actually considering the drivers or patterns of vulnerability.

3.3 | Approaches and methods used

The majority of papers (n = 64, 83%) applied quantitative assessment approaches, for example, modelling, statistics, and GIS-based analyses, or a combination of these. Only seven papers (9%) applied purely qualitative assessment methods, such as narratives, storylines or historical analyses. Six papers (8%) used mixed-methods approaches that integrated quantitative and qualitative methods.

Several papers (n = 23, 30%) used a combination of methods, for example, modelling (including hydrological models and modelling approaches using socio-economic data, that is, from a household survey, or a combination of the two such as hydrological simulations, flood damage models or models based on downscaled climate projections, etc.) and GIS, GIS and statistical analyses, or mixed-methods approaches including expert interviews, focus group discussions (FGDs), surveys, and so forth. Twenty-two papers (29%) applied modelling as the sole method. Nineteen papers (25%) used statistical methods such as regression analysis, descriptive statistics, composite risk indices, and so forth. Seven papers (9%) used qualitative analyses such as descriptive, narrative, and storylines. Five papers (7%) employed GIS as the main approach in flood risk assessment. However, GIS was usually applied together with modelling (n = 17, 22%) to assess flood risk and therefore was classified as combined methods in the review (Figure 4).

The majority of the papers analysed flood risk at the local level, for example, the research areas were located within one district or province (n = 54, 70%), and the regional level (n = 17, 22%) such as at the basin scale or in more than one province. Only six papers (8%) performed flood risk assessments at the national level, or the comparative analyses were carried out in more than one geographical region of Vietnam. Many papers (n = 43, 56%) assessed flood risk for present-day conditions or did not specify the temporal dimension (a snapshot analysis). Others considered dynamic trends in flood risk assessments, such as future flood risk scenarios or analyses of historical flood risk based on surveys of people's perception, loss and damage, or flood mark measurement for previous flood depth and duration (n = 34, 44%). Among the papers that assessed flood risk in Vietnam, only 36 papers (47%) considered future flood risk in their assessments. When future projections of flood risk or scenarios were supposed to be undertaken, a large number of these papers focused either only on the hazard (n = 16, 44%), exposure (n = 8, 22%), or a combined analysis of hazard, exposure or vulnerability (n = 8, 22%). Future vulnerability to flooding was assessed at a lower frequency (n = 4, 11%). These assessments of future flood risk had either no time frame (n = 26, 72%), or multiple time frames such as risk analyses for both 2050 and 2,100 (n = 6, 17%). Others addressed the period between 2050 and 2,100 (n = 4, 11%), and only one developed scenarios for 2050 (n = 1, 3%). All of the future-oriented assessments of vulnerability were published recently (i.e., in 2014 or thereafter). A lack of future vulnerability scenarios in risk assessments has been acknowledged by other authors, that is, due to the lack of socio-economic data for future vulnerability projections and the difficulties in measuring the complex and abstract phenomenon of social vulnerability in a highly dynamic context such as Vietnam (Garschagen & Kraas, 2010; Jurgilevich et al., 2017).

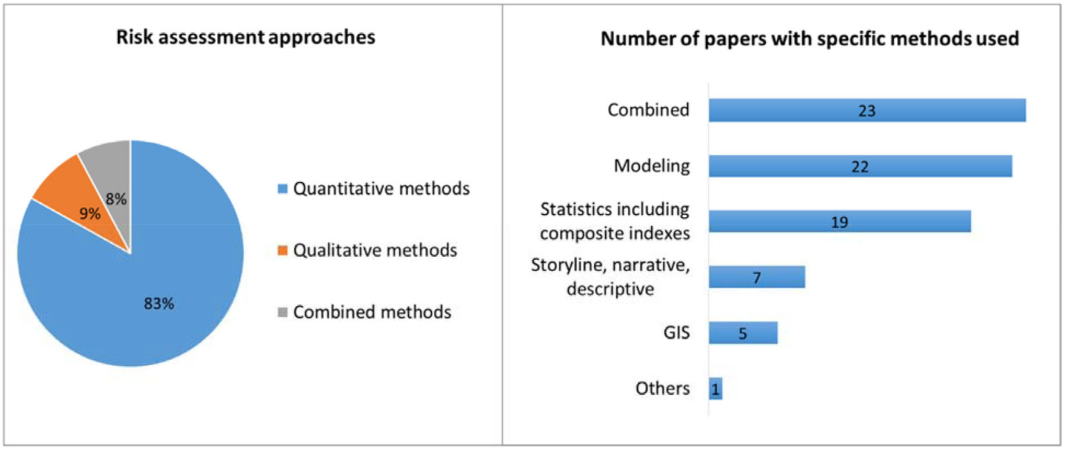

FIGURE 4 Risk assessment approaches and methods in the reviewed publications (n = 77)

TABLE 4 Main features and classification of drivers of flood risk in the reviewed papers

Drivers of flood risks ($n = 68$)	Frequency (mentioned/analysed)	Examples (in parentheses: Number of drivers that were mentioned/analysed)	Potential influence on hazard (H)/exposure (E)/vulnerability (V)
Physical and environmental drivers	110 (83/27)	Rainfall related issues—45 times (29/16)	H
		Physical and environmental characteristics of the researched areas—19 times (0/19)	H, E
		Tide—19 times (17/2)	H, E
		Increases in water discharge and river flow - 17 times (17/0)	H
		CC and SLR - 15 times (12/3)	H, E
		Storm surges, typhoons and cyclones—11 times (11/0)	H
		Low elevation or steep topography—10 times (10/0)	E
		Decline of buffer capacity—9 times (8/1)	H, V
		Changes in river characteristics—3 times (3/0)	H
		Land subsidence—3 times (3/0)	E
		Monsoons causing strong waves—2 times (2/0)	H
		Distance to rivers—2 times (0/2)	E
Economic drivers	34 (18/16)	Socio-economic conditions of households—15 times (0/15)	V
		Land-use changes and construction in flood-prone areas—7 times (6/1)	E, V
		Reservoir and dams—5 times (5/0)	H
		Economic development—2 times (2/0)	V
		Infrastructure conditions—2 times (2/0)	E, V
		Land-use type and farming practices—2 times (2/0)	E, V
		Deforestation—1 time (1/0)	H
Demographic drivers	22 (11/11)	Urbanisation—7 times (7/0)	E, V
		Demographics for example, population, household sizes and education, and so forth.—7 times (0/7)	V
		Coping capacity—4 times (0/4)	V
		Population growth—2 times (2/0)	E
		Ethnicities—2 times (2/0)	V
Socio-political drivers	15 (9/6)	Flood control measures—12 times (9/3)	H, E
		Social capital—2 times (0/2)	V
		Flood risk management—1 time (0/1)	V
Technical drivers	2 (1/1)	Early warning system—2 times (1/1)	V

3.4 | Drivers of flood risk

Of the reviewed papers, 68 assessments (88%) mentioned drivers of flooding, for example, in the description of research sites, or analysed the drivers of flood risk in the vulnerability or risk assessment. We restricted our review to drivers at the scale of the paper's analysis, for example, the drivers of flood risks within the specific case studies and excluded general drivers at the higher level, for example, those usually named in the introduction without further analyses. For the drivers that were mentioned, rainfall was most frequently considered the main cause of flooding (29 times). Other drivers included the tide (17 times), increases in water discharge and river flow (17 times), climate change (CC) and SLR (12 times), storm surges, typhoons and cyclones (11 times). Besides these physical drivers, a decline in buffer capacity, for example, due to surface area sealing and degradation of wetland area (8 times), urbanisation (7 times), and operation of dams and reservoirs (5 times), were usually named as the human-related drivers of flood risk and vulnerability (Table 4). Physical conditions of the researched areas were analysed most frequently (19 times) as the factors that characterise flood risk elements, followed by socio-economic conditions of households (16 times), rainfall related issues (16 times), and demographic characteristics of the households or areas (7 times). For a combination of all drivers that were mentioned and analysed in the reviewed papers, physical and environmental drivers such as rainfall, tide, CC and SLR were the most frequently mentioned (63 times), followed by socio-political drivers (25 times), economic drivers (16 times), demographic drivers (15 times), and technical drivers (2 times) (Table 4).

The drivers of flood risk recognised in the literature are usually interrelated. For example, in Ho Chi Minh City, high tides can lead to increased water levels, but also prevent water from withdrawing from the city, which is also determined by the poor drainage system (a socio-political driver; Duy, Chapman, & Tight, 2019). The reduced buffer capacity due to surface sealing and the decline of wetland areas is classified as a physical and environmental driver of flood risk in Ho Chi Minh City, itself largely driven by demographic and economic factors such as urbanisation and population growth, or construction in flood-retention areas (Storch & Downes, 2011). In addition, there is a lack of studies that consider the drivers of all flood risk elements since the majority focused on the drivers of a single risk element (Table 4). The drivers that influence the hazard element are mentioned most frequently (e.g., increased rainfall intensity and tides). Other drivers that influence the hazard element include changes in river characteristics due to human activities such as infrastructure development, dike, reservoir, and dam construction. Economic, demographic and socio-political drivers such as increased urbanisation, population growth, and poor drainage systems seem to affect the exposure and vulnerability elements of flood risk rather than the hazard component (Table 4).

3.5 | Solutions for flood risk reduction, risk transfer, flood risk management and adaptation

Out of the reviewed papers, 34 assessments (44%) offered solutions to reduce, manage or transfer flood risk. However, only 10 papers (29%) provided practical solutions, that is, solutions derived from the in-depth analyses of flood risks in the case studies (Table 5). A majority of papers ($n = 24$, 71%) mentioned solutions generally, that is, without in-depth analyses and a direct link to the analysed drivers of flood risks. For those that mentioned solutions, many studies ($n = 11$, 46%) called for improving flood risk assessment such as the development of flood risk maps ($n = 5$, 21%). Implementation of early warning information systems ($n = 10$, 42%) and an improvement of flood risk governance ($n = 7$, 29%) were also often advocated. For the papers that provided practical solutions with further analyses, structural measures such as dikes and infrastructure construction, or household measures such as elevating houses or application of water-proof structures, were usually considered ($n = 3$, 30%). Flood insurance and ecosystem-based adaptation were rarely considered in the reviewed papers (in one and two assessments respectively). For all solutions that were mentioned and analysed, non-structural measures were named 28 times, structural measures were mentioned seven times, and the combined measures were proposed six times.

The solutions that were derived from the case studies with detailed analysis often target exposure, vulnerability or a combination of different risk components. In contrast, the solutions that were only mentioned in general without providing a detailed analysis usually addressed the vulnerability, for example, by improving flood risk governance and preparedness. Measures such as improved flood risk management or early warning systems are likely to reduce one element of risk, for example, lower the exposure or improve adaptive capacity to floods. Household solutions, such as house elevating and water-proof installation, are more likely to reduce flood impact. In contrast, land use planning and ecosystem-based solutions are deemed to address all risk components (Table 5).

3.6 | Linkages between risk conceptualizations, drivers, proposed solutions and contexts

There is no clear evidence of the influence of different risk perspectives on the proposed solutions in the reviewed papers. However, linkages between the hazard or risk-based perspectives that were considered in the studies and risk assessment methods were observed (Figure 5). The modelling approach was applied repeatedly in hazard focused-studies, that is, 55% of hazard-focused papers applied the modelling approach. Combined methods such as an application of both GIS and modelling were employed more regularly in combined- and exposure-focused studies (44 and 30% respectively). In contrast, statistics (including composite risk indices) and qualitative methods such as narratives, descriptive analyses, and storylines prevailed in vulnerability-focused assessments (47 and 86% respectively). Regarding spatial scale, hazard perspective papers were more often regional (47%), while studies adopting other perspectives (e.g.,

TABLE 5 Proposed measures to reduce flood risks in the reviewed papers

Proposed measures ($n = 34$)	Frequency (mentioned/ analysed)	Classifications	Influence on hazard (H)/ exposure (E)/ vulnerability (V)	Examples
Improved flood risk assessment	12 (12/0)	Non-structural measures	E, V	Improving flood risk assessment is considered vital to support the decision-making process in disaster risk management in Vietnam (Luu et al., 2019)
Early warning systems and preparedness	10 (10/0)	Non-structural measures	V	Identifying risk areas, warning people about necessary measures, and providing safe places for evacuation in case of disaster events are important for disaster mitigation in Thua Thien Hue province (Phong, Shaw, Chantry, & Norton, 2009)
Land use planning and urban landscape design	9 (5/4)	Combined measures	H, E, V	In the Mekong Delta, land use planning should allow some flooding for agriculture in order to prevent catastrophic flooding (Le, Nguyen, Wolanski, Tran, & Haruyama, 2007) Consideration of flood risk in land use planning and the design of new projects is recommended for Ho Chi Minh City (Tu & Nitivattananon, 2011)
Flood governance	7 (7/0)	Non-structural measures	V	Implementation of management practices, sustainable resource use planning, and proactive mitigation measures are suggested to increase resilience to hazards and sustainability of natural and socio-economic systems in Thua Thien Hue province (Nhuan, Hien, Ha, Hue, & Quy, 2014)
Infrastructure building	6 (2/4)	Structural measures	H, E	A dike system from 12 to 15 m, combined with the operation of Hoa Binh reservoir upstream of the Red River, could protect Hanoi from floods such as the disastrous one in 1971, which had a water level of 14.13 m (Hung et al., 2007)
Awareness-raising	4 (3/1)	Non-structural measures	V	In Hanoi, providing local people with comprehensive training courses on adapting to urban flooding is proposed (Hung et al., 2007)
Combined structural and non-structural measures	4 (3/1)	Combined measures	H, E, V	Multiple measures are proposed to cope with the impacts of CC, and to improve the living conditions in Ho Chi Minh City, including the construction of levees together with urban landscape design (Lasage et al., 2014)
Household measures, for example, house elevation, water-proofing	3 (0/3)	Structural measures	E, V	The availability of boats for private transportation is an indicator of adaptation to flooding for rural households in the Mekong Delta (Ling, Tamura, Yasuhara, Ajima, & Van Trinh, 2015) In Ho Chi Minh City, dry-proofing is promising for household-scale adaptation because of its scalability, low cost, and relatively fast implementation (Scussolini et al., 2017)
Participation and cooperation	2 (2/0)	Non-structural measures	V	Experts, researchers, and scientists should be actively involved in decision-making processes for flood risk management (Luo et al., 2018)
Improve water supply systems and health services	2 (2/0)	Non-structural measures	V	Providing medical services to people during and after flooding is important to improve their mental health and to reduce the burden on medical treatments (Bich, Quang, Ha, Hanh, & Guha-Sapir, 2011)

TABLE 5 (Continued)

Proposed measures ($n = 34$)	Frequency (mentioned/analysed)	Classifications	Influence on hazard (H)/exposure (E)/vulnerability (V)	Examples
Livelihood and capacity enhancement	2 (2/0)	Non-structural measures	V	Encouraging the diversification of livelihood activities within the local capacity is one of the measures suggested to cope with flooding in Thua Thien Hue province (Okamoto, Kobayashi, & Tanaka, 2013)
Ecosystem solutions	2 (1/1)	Combined measures	H, E, V	Payment for environmental services (PES) schemes are proposed to enhance the motivation of farmers to establish soil conservation measures in sloping land (Schad et al., 2013)
Elevating roads and building	2 (0/2)	Structural measures	E	In Ho Chi Minh City, raising the ground level of buildings is one suggestion to reducing flood damage (Lasage et al., 2014)
Improved drainage systems	1 (1/0)	Hard measures	H, E	In Ho Chi Minh City, a priority adaptation strategy is installing and upgrading floodwater and rainwater storage facilities to reduce water overflow and reuse rainwater for irrigation and other purposes (Tu & Nitivattananon, 2011)
Flood insurance	1 (1/0)	Non-structural measures	V	Establishing a flood insurance market is suggested for Can Tho City as well as supporting schemes to facilitate the quick recovery of flood-affected businesses (Chinh et al., 2016)

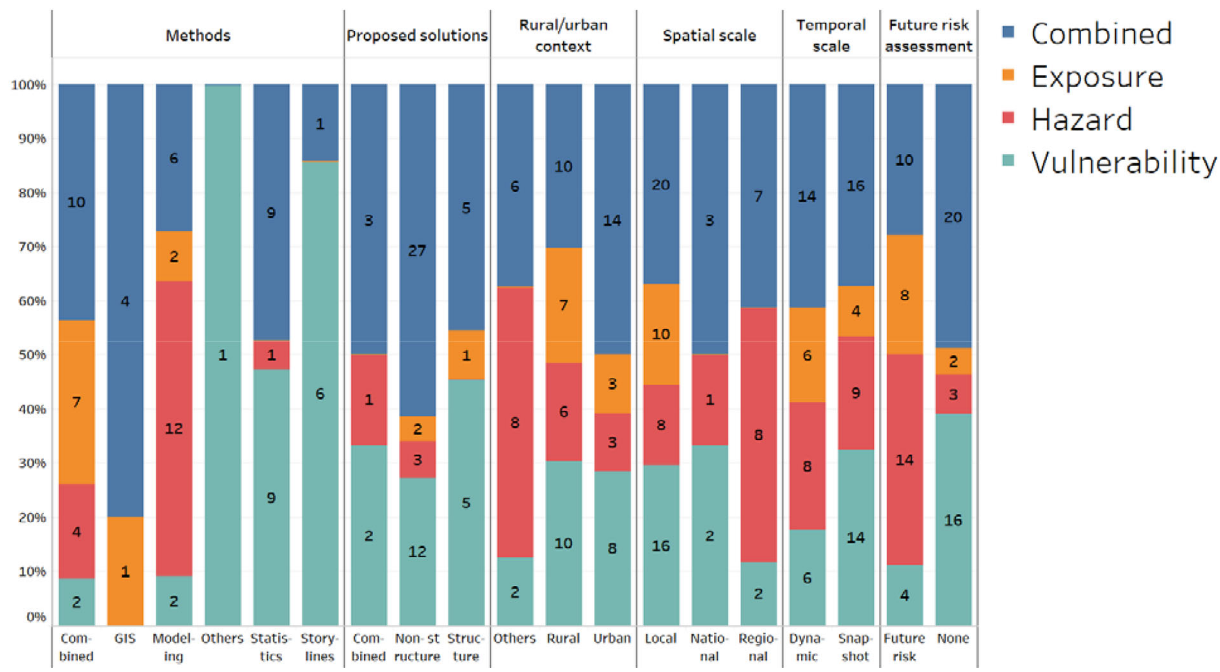

FIGURE 5 Risk assessment perspectives in the reviewed papers and their variation across contexts and approaches (the number of papers per category was shown in each column)

exposure and vulnerability) were usually addressed at the local level (100 and 80% of studies, respectively). For the temporal dimension, the assessments that employed a vulnerability perspective were more likely to address flood risk as a snapshot (70%) than other studies adopting an exposure (40%), hazard (53%), or multiple flood risk perspective (53%). Risk perspectives were also applied differently between rural and urban contexts (Figure 5). The combined and vulnerability perspectives were regularly acknowledged in both assessments in urban and rural contexts. Nevertheless, studies carried out in the urban context more regularly addressed a combination of different flood risk elements (47% of papers) than studies in rural areas (33%). Assessments that were undertaken in rural areas also targeted exposure (70%) and hazard (35%) more often than studies carried out in urban areas (30 and 18% of studies, respectively).

Several commonalities and differences of drivers of flood risk were also observed between locations and contexts. Physical and environmental factors (e.g., rainfall, physical, and environmental characteristics of the researched areas, tide, etc.) and economic-related drivers, including the implementation of dikes or construction in flood-prone areas, as well as economic development, were mentioned most frequently among locations and contexts (Figure 5). The drivers of flood risk may also be influenced by the flood types and their characteristics, for example, the magnitude of the flood hazard in specific regions. For instance, in the Northeast, Northwest and North Central coast, physical and environmental drivers dominated other drivers of flood risk. In the Northeast and Northwest, flash floods were the only flood type analysed in the reviewed literature, while in the North Central Coast, floodwaters typically rise rapidly with strong flow velocities. Thus, other economic, socio-political, and demographic drivers may be less recognisable as influencing factors on flood risk than physical and environmental drivers in these areas.

There are some variations in the drivers of flood risk among urban and rural settings. In rural areas, physical and environmental as well as socio-political factors were more often considered as the drivers of flood risk, whereas in the cities, economic and demographic drivers such as urbanisation, population growth, and construction in flood-prone areas were more regularly mentioned/analysed (Figure 6). A possible explanation would be the high values of assets and population exposed to flooding events in the cities. In urban areas, infrastructure status and the values of units that are exposed to flooding are important factors characterising flood risks. For instance, in Ho Chi Minh City, Binh Thanh district has more concrete surface area, making the district more vulnerable to flooding (Tu & Nitivattananon, 2011). Economic drivers were also acknowledged more regularly in the hinterland than in the coastal areas. In contrast, socio-political drivers are more often considered in coastal areas.

4 | PERSISTENT GAPS AND FUTURE DIRECTIONS

The literature review revealed that various risk definitions and conceptualizations have been applied in flood risk assessments in Vietnam. Both hazard-focused and vulnerability/risk-based perspectives have been used in flood risk assessments across the country. However, hazard-focused assessments still dominated. The majority of papers did not provide a clear definition of risk in their assessments, which might constrain the understanding

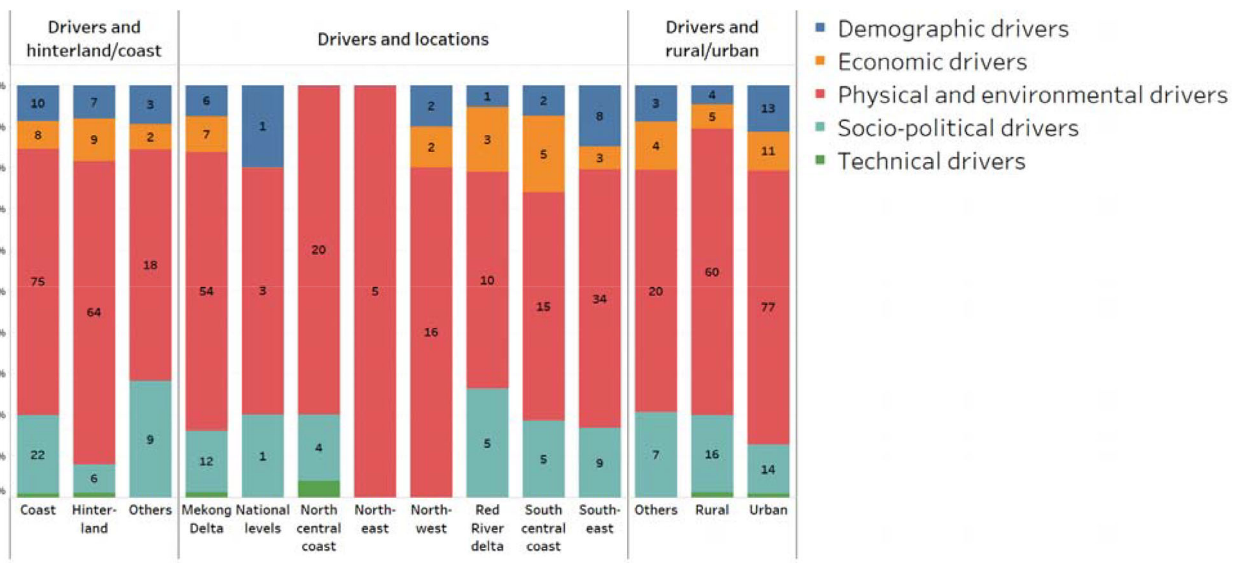

FIGURE 6 Drivers of flood risk in the reviewed papers across locations and contexts (the frequency of drivers per category was shown in each column)

and use of the assessment results, as well as the transfer of results to other regions. In risk assessment, a concrete definition of risk is important to frame the spatio-temporal boundaries of the research and to allow a better understanding and synthesis of study results. Defining risk may also help to deconstruct risk into different elements for integrated spatial risk analyses that also consider hazard, exposure and vulnerability, which is currently rarely applied in flood risk assessments in Vietnam. In flood risk management literature globally, there is still a divide between the social and the natural sciences, in which the first perspective often addresses social interactions and flood risk governance, and the latter focuses on tools to predict flood probabilities and assess vulnerability (Morrison et al., 2018). An inclusion of socio-economic data into risk and vulnerability assessment has also been proposed in other review studies of climate risk, such as a consideration of socially vulnerable populations for community flood risk management (Jurgilevich et al., 2017; Tyler, Sadiq, & Noonan, 2019). This review thus advocates a departure from the current focus on flood hazards and single method use (e.g., only flood hazard modelling), towards an application of integrated perspectives that consider flood hazards, exposure of humans, ecosystems, infrastructure and (cultural, economic) assets, and systems' vulnerabilities as well as a variety of assessment methods.

The literature review revealed a lack of assessments that considered various drivers of multiple risk elements. Many papers mentioned the drivers of flood risk generally without contextual analyses. Therefore, future flood risk assessments should address multiple drivers of all flood risk elements. Although numerous papers have suggested solutions for reducing flood risk, there is little evidence whether the analyses of drivers of flood risk led to the development of the proposed solutions. In addition, studies that engaged with stakeholders during the assessments and development of solutions were very limited. This is surprising given that relevant national-level policies in the country emphasise the importance of the active involvement of all groups of stakeholders and the mainstreaming of climate change issues and disaster prevention into socio-economic, sector and spatial development plans at all levels (GoV, 2008, 2011, 2012a, 2013). As revealed in a literature review of flood risk management globally, only 7% of the reviewed papers could be classified as 'research on practice' theme (Morrison et al., 2018). Thus, an in-depth analysis of drivers is needed that can lead to the development of practical measures (e.g., through active engagement with local stakeholders) to reduce flood risk. Furthermore, the assessments of future flood risk in the literature focused strongly on climate variability and hazard exposure, while vulnerability or a combination of risk elements were adopted less regularly. Today, it is well recognised that flood risk is dynamic and several risk elements would be largely modified by an alteration of even one single driver (Merz et al., 2014). Therefore, future projections of flood risk need to take into account dynamic changes of drivers and their influence on all risk elements (Tanoue et al., 2016). At the moment, numerous flood projection models consider flooding as a static and local process (Merz et al., 2014), and thus the projection of future flood risk does not take into account environmental change, societal transformation, or the effects of human behaviour, risk reduction and adaptation. A consideration of the dynamics of drivers and their influence on future risk elements is relevant not only for flood risk projection but also for flood risk management, since the solutions that aim to tackle current drivers of risk at a particular place would introduce more or other drivers, or transfer risk spatially (Jurgilevich et al., 2017). At present, the flood risk management planning has been carried out for almost all major basins in Vietnam. However, the planning is still spatially limited to the catchment scale, whereby the adjacent areas and estuaries are not considered (Quynh & Thanh, 2016). Except for some studies using statistical data without field observation or field data, all papers in this review analyse flood risk within administrative regions or basin scales in the country without consideration of transboundary approaches. This is different from the European Union approach to flood risk management, where the assessments and management of flood risk consider the transboundary basin that is divided into different bioregional scales (Priest et al., 2016). In Vietnam, flood risk management activities involve various agencies across administrative levels. At the national level, the activities for natural hazard prevention, responses and preparedness are in charge of almost all ministries, in which the Central Steering Committee for Natural Disaster Prevention and Control, the National Committee for Incident, Disaster Response, Search and Rescue, and the Ministry of Agriculture and Rural Development are the main actors. The people's committee at the provincial level is tasked to implement flood risk management strategies at lower levels (MARD, 2019). In order to improve flood risk management, it is recommended that scientists and experts should be involved in the flood risk steering committee and decision-making (Chinh, Von Meding, & Kanjanabootra, 2018; Hoang et al., 2018). Financial challenges related to budget allocation, however, would be one of the barriers that hinder the participation process (Chinh et al., 2018).

From an empirical perspective, one suggestion that was proposed in the literature review is the development of risk transfer solutions such as flood risk insurance, the uptake for which remains low in Vietnam (Reynaud, Nguyen, & Aubert, 2018). Climate risk-transfer solutions such as flood risk insurance are proven to be successful to help people quickly recover from flood damage (Chinh et al., 2016; Triet et al., 2018) and therefore can be considered a viable option for flood risk management in the country. In addition, ecosystem-based solutions are rarely considered as potential flood reduction or adaptation measures in the reviewed literature, with only two papers acknowledging these solutions, that is, paying for ecosystem services. The National Climate Change Strategy of Vietnam (GoV, 2011) recognises the relevance of ecosystem-based solutions, however, and the National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020 also proposes both structural (e.g., protection and upgrade of dikes and reservoirs) and non-structural (e.g., improvement of the legislative and policy frameworks, awareness-raising, etc.) measures to reduce flood risk (GoV, 2007). In Central Vietnam, initiatives to implement ecosystem-based measures for flood risk reduction were carried out, for example, by restoring water bodies in the cities and mangrove forests along the coast (CSRD, 2018). Further consideration and analyses of the role of ecosystem-based adaptation to flooding in Vietnam are therefore recommended as part of an overall risk reduction or adaptation strategy. These solutions could be linked to enhancing the provision of ecosystem services such as improvements of flood-based livelihoods (Tran, van Halsema, Hellegers, Ludwig, & Seijger, 2018), or an application of critical green infrastructures to mitigate flood hazards (Sebesvari et al., 2019). Such ecosystem-based solutions have been considered to address the underlying drivers of flood risks and provide additional benefits without compromising other risk elements.

Other recommendations for future flood risk assessments in Vietnam include focusing more on small-sized cities, for example, the ones that are provincially administered and categorised as lower than category II by the Vietnamese government. These cities often face the highest vulnerability and possess the least capacity to deal with climate change yet are currently often neglected in science and policy (Birkmann, Welle, Solecki, Lwasa, & Garschagen, 2016). In addition, many peri-urban and rural areas adjacent to urban areas in Vietnam are urbanising rapidly, leading to the encroachment of cities into rural and potential flood-prone areas, which often lack sufficient academic and political attention, particularly in Vietnam (Garschagen, Renaud, & Birkmann, 2011). In this context, exploring the drivers leading to present day flood risk in urban agglomerations provides practical implications for risk reduction planning in areas facing rapid urbanisation, such as spatial urban planning in transition areas. In addition, flood risk assessments for the Central Highlands are crucial, given the area's high risk to fluvial and flash floods following torrential rains (CCFSC, 2016). As of yet, there have been no flood risk assessments carried out in this area in the literature.

5 | CONCLUSIONS

Presently, several different risk conceptualizations and definitions have been applied for flood risk assessments in Vietnam. A conceptualization of flood risk focusing on hazard or risk/vulnerability perspectives could influence the choices of the assessment approach (e.g., the hydrological modelling and GIS-based approaches that were often employed in hazard-focused studies). An incorporation of hazard, exposure and vulnerability-related elements in flood risk definitions and conceptualization is much needed among flood risk assessments in Vietnam, for example, by adopting the latest risk definitions and approaches of IPCC in the SREX report (IPCC, 2012) and the subsequent fifth Assessment Report (IPCC, 2014). A conceptualization of flood risk that integrates environmental, physical, social, economic and institutional (i.e., governance-related) aspects is vital to explore the root causes of flood risk across geographies, sectors, and within regions with different socio-economic conditions. The integrated flood management approach or several frameworks in the field of social-ecological assessment, resilient management, and adaptive risk management, etc. that address the linkage between social and natural systems at both local and basin scales therefore could be useful for flood risk assessments and management.

In addition, this literature review has revealed various drivers of flood risk in Vietnam, whereby physical and environmental drivers were most widely considered. It is thus necessary to enhance the exploration of social, economic and political or governance-related drivers of flood risk since it has been revealed that in urban flooding in Southeast Asia, social conditions such as population density, public awareness, and governance are the main factors influencing the number of flood fatalities (Osti, Hishinuma, Miyake, & Inomata, 2011). Drivers of flood risk also varied across contexts, for instance, between rural and urban areas. Thus, analyses of the drivers of flood risk and the development of solutions for reducing flood risk in the country should pay attention to these contextual differences.

Flood risk assessments for transboundary rivers and basins should also be carried out to foster an integrated and spatial flood risk management beyond basin and administrative levels, for example, a cross-boundary flood risk management approach. In addition, future-oriented risk assessments that acknowledge dynamic changes among all risk elements are desired to narrow the existing gaps of future risk assessments which are currently strongly hazard-focused. Combining different methods and engaging local stakeholders in the assessments and developments of solutions are therefore recommended to address the contextual differences and data constraints on socio-economic projection in future flood risk assessments.

ACKNOWLEDGEMENTS

This research was part of the FloodAdaptVN project (Grant No. 01LE1905G) funded by the German Federal Ministry of Education and Research (BMBF) through its Research for Sustainable Development (FONA) program. The authors also would like to thank Dr. Shengle Yin for her support in cross-checking the paper coding, Ms. Isabel Meza for her advice on the analysis, and Mr. Harrhy James for proofreading of the manuscript.

AUTHOR CONTRIBUTIONS

Minh Tu Nguyen, Michael Hagenlocher, Zita Sebesvari, and Maxime Souvignet designed the research approach and the review strategy. The review was conducted by Minh Tu Nguyen, Michael Hagenlocher, Zita Sebesvari, and Maxime Souvignet under the overall supervision of Michael Hagenlocher. All authors contributed to the interpretation of the results and the development of the manuscript. Minh Tu Nguyen drafted the manuscript with inputs from all authors. All authors approved the manuscript.

DATA AVAILABILITY STATEMENT

I confirm that my article contains a Data Availability Statement even if no data is available (list of sample statements) unless my article type does not require one. I confirm that I have included a citation for available data in my references section, unless my article type is exempt.

ORCID

Minh Tu Nguyen https://orcid.org/0000-0001-6268-3589
Felix Bachofer https://orcid.org/0000-0001-6181-0187
Andreas Braun https://orcid.org/0000-0001-8630-1389
Matthias Garschagen https://orcid.org/0000-0001-9492-4463
Michael Hagenlocher https://orcid.org/0000-0002-5254-6713

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How to cite this article: Nguyen MT, Sebesvari Z, Souvignet M, et al. Understanding and assessing flood risk in Vietnam: Current status, persisting gaps, and future directions. *J Flood Risk Management*. 2021;e12689. https://doi.org/10.1111/jfr3.12689

APPENDIX 1: List of relevant papers for the review.

No.	Reviewed paper
1.	Älgå, A. *et al.* (2018) 'Hope for the best, prepare for the worst—An assessment of flood preparedness at primary health care facilities in central Vietnam', *International Journal of Environmental Research and Public Health*, 15(12). doi: 10.3390/ijerph15122689.
2.	An, D. T. N. and Kumar, L. (2017) 'Application of remote sensing and GIS-based hydrological modelling for flood risk analysis: a case study of District 8, Ho Chi Minh city, Vietnam', *Geomatics, Natural Hazards and Risk*. Taylor & Francis, 8(2), pp. 1792–1811. doi: 10.1080/19475705.2017.1388853.
3.	Anh, H. H. *et al.* (2018) 'Examining the interaction of flood vulnerability determinants in Cambodia and Vietnam using partial least squares structural equation modeling', *Water Policy*, 20(6), pp. 1256–1278. doi: 10.2166/wp.2018.198.
4.	Apel, H. *et al.* (2016) 'Combined fluvial and pluvial urban flood hazard analysis: Concept development and application to Can Tho city, Mekong Delta, Vietnam', *Natural Hazards and Earth System Sciences*, 16(4), pp. 941–961. doi: 10.5194/nhess-16-941-2016.
5.	Balica, S. *et al.* (2014) 'Flood impact in the Mekong Delta, Vietnam', *Journal of Maps*. Taylor & Francis, 10(2), pp. 257–268. doi: 10.1080/17445647.2013.859636.
6.	Bich, T. H. *et al.* (2011) 'Impacts of flood on health: epidemiologic evidence from Hanoi, Vietnam.', *Global health action*, 4, p. 6356. doi: 10.3402/gha.v4i0.6356.
7.	Binh, L. T. H., Umamahesh, N. V. and Rathnam, E. V. (2019) 'High-resolution flood hazard mapping based on nonstationary frequency analysis: case study of Ho Chi Minh City, Vietnam', *Hydrological Sciences Journal*. Taylor & Francis, 64(3), pp. 318–335. doi: 10.1080/02626667.2019.1581363.
8.	Boateng, I. (2012) 'GIS assessment of coastal vulnerability to climate change and coastal adaption planning in Vietnam', *Journal of Coastal Conservation*, 16(1), pp. 25–36. doi: 10.1007/s11852-011-0165-0.
9.	Bubeck, P. *et al.* (2012) 'Do flood risk perceptions provide useful insights for flood risk management? Findings from central Vietnam', *Journal of Flood Risk Management*, 5(4), pp. 295–302. doi: 10.1111/j.1753-318X.2012.01151.x.
10.	Bui, D. T., Tsangaratos, P., et al. (2019) 'Flash flood susceptibility modeling using an optimized fuzzy rule based feature selection technique and tree based ensemble methods', Science of the Total Environment. Elsevier B.V., 668, pp. 1038–1054. doi: 10.1016/j.scitotenv.2019.02.422.
11.	Casse, T., Milhøj, A. and Nguyen, T. P. (2015) 'Vulnerability in north-central Vietnam: do natural hazards matter for everybody?', *Natural Hazards*. Springer Netherlands, 79(3), pp. 2145–2162. doi: 10.1007/s11069-015-1952-y.
12.	Chau, V. N., Cassells, S. and Holland, J. (2015) 'Economic impact upon agricultural production from extreme flood events in Quang Nam, central Vietnam', *Natural Hazards*, 75(2), pp. 1747–1765. doi: 10.1007/s11069-014-1395-x.
13.	Chinh, D. T. *et al.* (2016) 'The 2011 flood event in the Mekong Delta: preparedness, response, damage and recovery of private households and small businesses', *Disasters*, 40(4), pp. 753–778. doi: 10.1111/disa.12171.
14.	Chinh, D. T. *et al.* (2017) 'Flood loss models and risk analysis for private households in can Tho City, Vietnam', *Water (Switzerland)*, 9(5). doi: 10.3390/w9050313.
15.	Dang, N. M., Babel, M. S. and Luong, H. T. (2011) 'Evaluation of food risk parameters in the Day River Flood Diversion Area, Red River Delta, Vietnam', *Natural Hazards*, 56(1), pp. 169–194. doi: 10.1007/s11069-010-9558-x.
16.	DiGregorio, M. (2015) 'Bargaining with disaster: Flooding, climate change, and urban growth ambitions in quy nhon, vietnam', *Pacific Affairs*, 88(3), pp. 577–597. doi: 10.5509/2015883577.
17.	Dinh, Q. *et al.* (2012) 'Climate change impact on flood hazard, vulnerability and risk of the Long Xuyen Quadrangle in the Mekong Delta', *International Journal of River Basin Management*, 10(1), pp. 103–120. doi: 10.1080/15715124.2012.663383.
18.	Duy, P. N. *et al.* (2018) 'Increasing vulnerability to floods in new development areas: evidence from Ho Chi Minh City', *International Journal of Climate Change Strategies and Management*, 10(1), pp. 197–212. doi: 10.1108/IJCCSM-12-2016-0169.
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No.	Reviewed paper
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25.	Hung, H. V., Shaw, R. and Kobayashi, M. (2007) 'Flood risk management for the RUA of Hanoi: Importance of community perception of catastrophic flood risk in disaster risk planning', *Disaster Prevention and Management: An International Journal*, 16(2), pp. 245–258. doi: 10.1108/09653560710739568.
26.	Huong, D. T. V. and Nagasawa, R. (2014) 'Potential flood hazard assessment by integration of ALOS PALSAR and ASTER GDEM: a case study for the Hoa Chau commune, Hoa Vang district, in central Vietnam', *Journal of Applied Remote Sensing*, 8 (1), p. 083626. doi: 10.1117/1.jrs.8.083626.
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31.	Le, T. V. H. *et al.* (2007) 'The combined impact on the flooding in Vietnam's Mekong River delta of local man-made structures, sea level rise, and dams upstream in the river catchment', *Estuarine, Coastal and Shelf Science*, 71(1–2), pp. 110–116. doi: 10.1016/j.ecss.2006.08.021.
32.	Leitold, R. and Diez, J. R. (2018) 'Exposure of manufacturing firms to future sea level rise in Ho Chi Minh City, Vietnam', *Journal of Maps*, 5647. doi: 10.1080/17445647.2018.1548385.
33.	Ling, F. H. *et al.* (2015) 'Reducing flood risks in rural households: survey of perception and adaptation in the Mekong delta', *Climatic Change*, 132(2), pp. 209–222. doi: 10.1007/s10584-015-1416-0.
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36.	Luu, C. and von Meding, J. (2018) 'A flood risk assessment of Quang Nam, Vietnam using spatial multicriteria decision analysis', *Water (Switzerland)*, 10(4), pp. 1–16. doi: 10.3390/w10040461.
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40.	McElwee, P. *et al.* (2017) 'Flood vulnerability among rural households in the Red River Delta of Vietnam: implications for future climate change risk and adaptation', *Natural Hazards*. Springer Netherlands, 86(1), pp. 465–492. doi: 10.1007/s11069-016-2701-6.
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