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A systematic investigation of flood resilience measures in the Mekong River Basin

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ABSTRACT

The Mekong River has encountered severe flooding challenges due to increasingly extreme weather conditions. Despite these challenges, residents of the Mekong River Basin (MRB) have developed and demonstrated remarkable flood resilience in various ways, enabling a dynamic and thriving socio-economic system in the flood-prone environment. This study presents a systematic review and meta-analysis based on 460 search results from Scopus and Web of Science datasets, covering literature from 1999 to 2024, focused on the MRB. The review aims to investigate the measures developed by people in the MRB to improve their flood resilience, as determined through a comprehensive scoping review of peer-reviewed literature. The review revealed the following findings: (1) A total of 85 measures were identified and categorized into nine measure groups and three approaches based on their characters, (2) statistical analysis indicates a rising trend in stakeholder cooperation, with over 66 % of the total mentioned measures involving coordinated approaches rather than being strictly top-down or bottom-up, (3) infrastructure and engineering investments, as well as advancements in agricultural technology, were the dominant measures observed across Mekong River Basin countries, and (4) a Venn diagram illustrates overlapping measures applied across various countries, with Vietnam, Cambodia, and Thailand contributing significant efforts to improving flood resilience. This study provides valuable insights for policymakers and researchers into the flood resilience situation within the region, supporting the development of effective future flood management frameworks and research approaches.

1. Introduction

Climate change has emerged as one of the most significant concerns with changes in precipitation patterns and the hydrological cycle across multiple spatial and temporal scales. These changes exacerbate the formation of runoff and disrupt regimes, thereby increasing the frequency of floods (Nie et al., 2012; Wang et al., 2013; Wu et al., 2016). In addition, sea level rise has contributed to heightened flood risk in coastal areas. Without further adaptation efforts, flood risks are expected to increase remarkably by the end of this century (Liang and Ding, 2017; Tu et al., 2021). These events have already exerted considerable negative influence on both the natural world and human society, leading to economic losses and hindering the development of communities near waterways (Lebel et al., 2020; Try et al., 2020). Frequent flooding may also put more stress on the provision of human health care services, water management, infrastructure maintenance, and water supply (Yang et al., 2013; Yang et al., 2018; Yang, 2020).

The Mekong River Basin (MRB) has faced particularly severe flooding challenges due to increasingly extreme weather conditions and minor causes like deforestation and irrigation dams (Vo and Mushtaq, 2011; Baiyinbaoligao et al., 2020). However, despite the damages, annual floodwaters also bring significant economic benefits to the residents, and people have adapted to floods over time (Chapman et al., 2016; Hoang et al., 2018), making it become a typical study area worldwide. Therefore, the need for an alternative flood risk management strategy (FRM), '*resilience*', is highlighted (McClymont et al., 2020). Studying resilience is significant in identifying and assessing environmental impacts and social feedback (Yang et al., 2021).

The word '*resilience*', coming from the Latin *resiliō* (Folke, 2006), was defined in the 2014 IPCC Report as the capacity of interdependent social, economic, and ecological systems to adapt to a potentially dangerous event, trend, or disruption by changing or reconfiguring in a way that preserves their fundamental identity, structure, and function. The ability to adapt, learn, and/or transform is a good trait that

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characterizes resilience (IPCC, 2014). The resilience approach is a dynamic perspective that is system-oriented and views adaptive capacity as a fundamental aspect of resilient socio-ecological systems (Nelson et al., 2007).

Along with engineering and ecological resilient conceptualizations, the social-ecological concept, or adaptive resilience, to flooding nurtures society's capacity for short-term changes while remaining open to long-term transformation strategies (Zevenbergen et al., 2020). "Adaptive capacity" is limited to the social realm, where actors are able to plan and predict adaptive reactions (Zevenbergen et al., 2020). It promotes actions from prevention to preparedness and encourages participation, collective action, and learning to influence flood risks (Zevenbergen et al., 2020). Inside, flood resilience measures may include implementing various flood management practices in conjunction with citizen participation and individual-level adaptation (Kuhlicke et al., 2020; Matczak and Hegger, 2021).

Evaluating how and why a community, associated with its interconnected communities, maintains and develops over time to identify areas that need improvement and lack resilience is therefore an important area of study (Yang et al., 2021; Zhu and Liu, 2021). This evaluation maximizes the use of resources and distributes findings to interested parties (Serre and Heinzlef, 2018).

Recently, there have been numerous research articles studying flood-related topics and adaptive resilience to flooding in the MRB countries, particularly in Vietnam and the Vietnamese Mekong Delta (VMD) (Harish et al., 2023). Most of these studies have employed qualitative methodologies, such as interviews (Yang and Andriesse, 2021; Hoang et al., 2023), literature review and document analysis of reports, policies, programs (Nguyen et al., 2021), and some previous research articles (Thomas, 2020; Tompkins et al., 2020; Palazzo et al., 2022). Other studies have used literature review (Laeni et al., 2021; Tang et al., 2022a; Tri et al., 2023) or systematic reviews in combination with primary research tasks (Tang et al., 2022b). However, most of the articles focused on independent respective countries, and relatively few have applied a systematic review to synthesize and statistically analyze multiple research articles from reputable database systems over several years. An updated systematic review would provide an overview of the application of flood measures, as well as how flood resilience has evolved across MRB.

This study was designed to report a systematic review and meta-analysis of 460 search results collected from Scopus and Web of Science datasets from 1999 to 2024. Excel spreadsheets for thematic/content analysis with coding approaches and a meta-analysis were applied during the process. The review aims to identify and categorize flood resilience measures implemented across MRB countries. In addition, the study explores the commonalities and gaps in the implementation of these measures within the region and provides policy recommendations to enhance the coordinated flood resilience strategies across the MRB.

2. Methodology and materials

2.1. Research area

The Mekong River is one of the largest rivers in Southeast Asia, with a length of 2750 km (Fig. 1) (Baiyinbaoligao et al., 2020). It originates as the Lancang River in Qinghai Province, China, and becomes the Mekong River at the border of the Xishuangbanna Dai Autonomous Prefecture in Yunnan Province, where China meets Myanmar and Laos. After leaving China, the Mekong River flows from the mountains along the China-Myanmar-Laos borders, through plateaus in Laos and north-eastern Thailand, and into the plains of Cambodian and southern Vietnam (VMD) before emptying into the East Sea of Vietnam (MRC, 2005; Baiyinbaoligao et al., 2020; MRC, 2022). Hence, the MRB covers a large basin area of 630,000 km^2, shared by Myanmar (4 %), Laos (32 %), Thailand (29 %), Cambodia (25 %), and Vietnam (10 %) (MRC, 2005).

There are two distinct seasons in the MRB due to its monsoonal climate, including dry season (December-May) and wet season (June – November), with rainfall usually starting in May and peaking in July in 2008–2018, but it shifted half a month later and peaked in August and June in 2019–2020 (Fig. 2) (MRC, 2005, 2020). As a result, the basin receives around 345 km^3 of the annual highest discharge between July and October that sustain habitats and livelihoods (MRC, 2005). The Mekong River sustains approximately 70 million people in the MRB, most of whom live near the river and depend on it for their livelihoods (Campbell, 2016; Wang et al., 2017; Try et al., 2020).

However, annual flooding in the MRB has caused severe damage in areas such as Savannakhet, Pakse, Kratie, and the VMD, with the highest deaths years being 2000 (825), followed by 2001 (489), 2011 (396), 2013 (247), and 1996 (173) (Try et al., 2019; Chen et al., 2020; Try et al., 2020). Additionally, major floods damaged over 2.50 million ha of farmland in 2000 and approximately 500,000 ha in 2011, with the 2000 "century" flood alone costing the VMD around $500 million (Vo and Mushtaq, 2011; Chen et al., 2020).

Despite challenges, MRB residents have developed and demonstrated remarkable flood resilience through infrastructure, agriculture, community networks, early warning, and cultural practices, which are vital for climate adaptation and sustainable development in the region.

2.2. Systematic review methodology

The study aimed to synthesize and analyze scientific papers on adaptive flood measures in the MRB. Web of Science (WoS) and Scopus are among the most effective and comprehensive sources of peer-reviewed literature due to their functions as search engines for other databases (Levay et al., 2016; Yung and Khoo-Lattimore, 2019; Perkins et al., 2020). Additionally, they offer advanced search capabilities and index reputable journals (Centobelli et al., 2018). Hence, these platforms are often chosen by researchers worldwide (McClymont et al., 2020; Gulde et al., 2025). Therefore, Scopus and WoS databases were chosen to search for peer-reviewed and high-quality papers published without a time limit up to June 2024. The authors chose not to include grey literature due to our initial objective of focusing solely on scientific papers. In addition, most grey literature is often not standardized or comparable, as each nation has their own policy framework. Moreover, grey documents are difficult to collect comprehensively because they are vast and often unlimited in scope. Including only some of them risks omitting others, making it impossible to cover all relevant material and potentially leading to bias. Only peer-reviewed papers and book chapters from journals and conferences published in English were selected because the analysis of flood resilience in FRM focused solely on how academia uses the term. The final search was conducted on 15 July 2024 using two sets of search queries:

WoS database: TS= ("Mekong" OR "Me kong") AND TS= (flood*) AND TS= ("resilien*" OR "adapt*");

Scopus database: TITLE-ABS-KEY("Mekong" OR "Me kong") AND TITLE-ABS-KEY(flood*) AND TITLE-ABS-KEY("resilien*" OR "adapt*")

The "Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) flowchart" (Fig. 3), which includes four main stages, illustrates the content analysis of the systematic literature review and the extraction of key information (Moher et al., 2010). Two independent authors screened each record for eligibility. Discrepancies were resolved through discussion, and, when necessary, a third author(s) was consulted to reach consensus.

In the screening phases, all identified publications were assessed for relevance based on the study's question, with inclusion or exclusion determined accordingly. The screening process involved two main stages: (1) title and abstract screening to filter out papers without flood-related topics, and (2) full-text screening to go into detail with eligibility about flood resilience-related topics. Papers meeting the criteria were marked as "Included", while others were "Excluded". The screening process was done with all uncertainties resolved collaboratively.

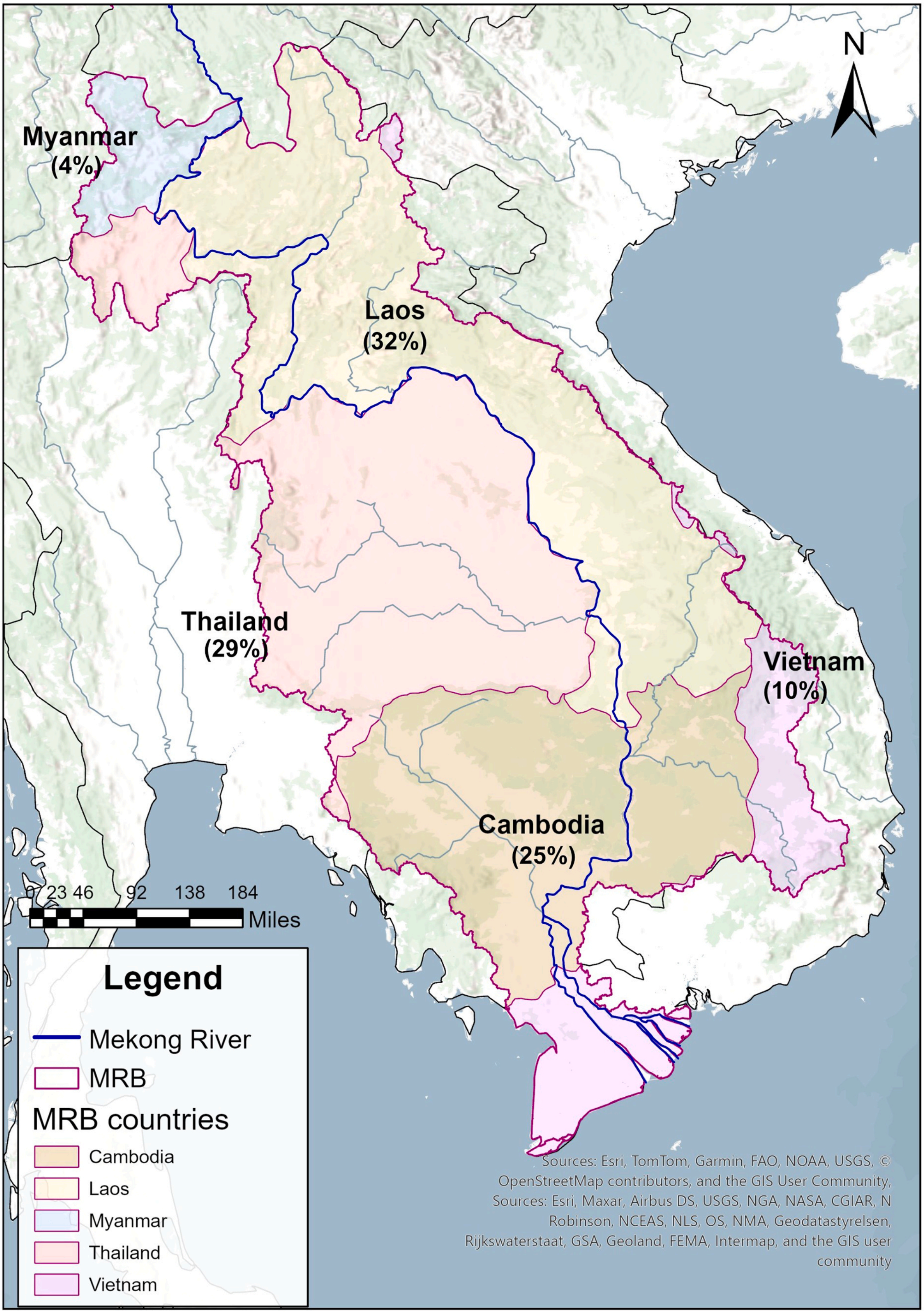

Fig. 1. The Mekong River runs from the border of China with Myanmar and Laos, through Myanmar, Laos, Thailand, Cambodia, and the Vietnamese Mekong Delta, and ends up in the East Sea of Vietnam.

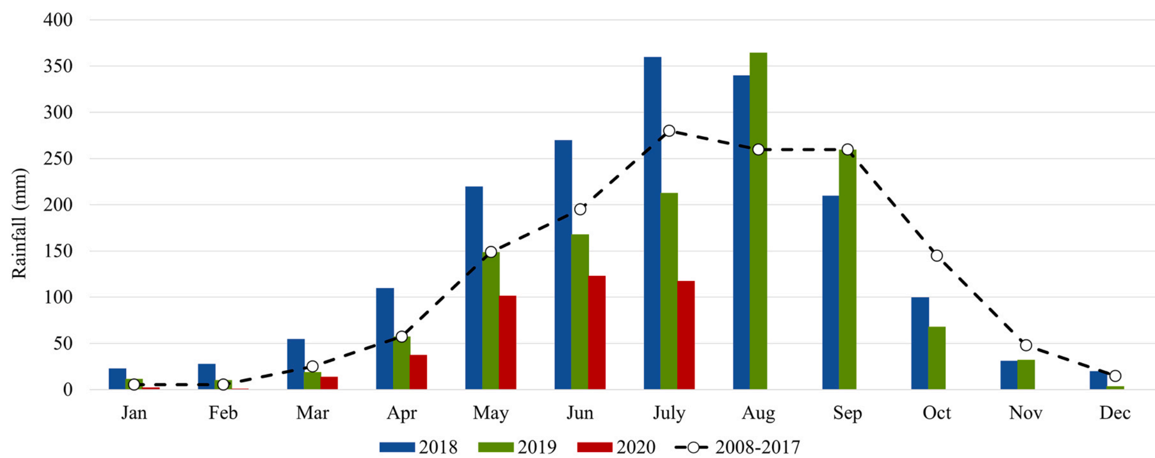

Fig. 2. Total monthly rainfall in the Lower MRB from 2008 to 2020 from 119 stations adopted from (MRC, 2020).

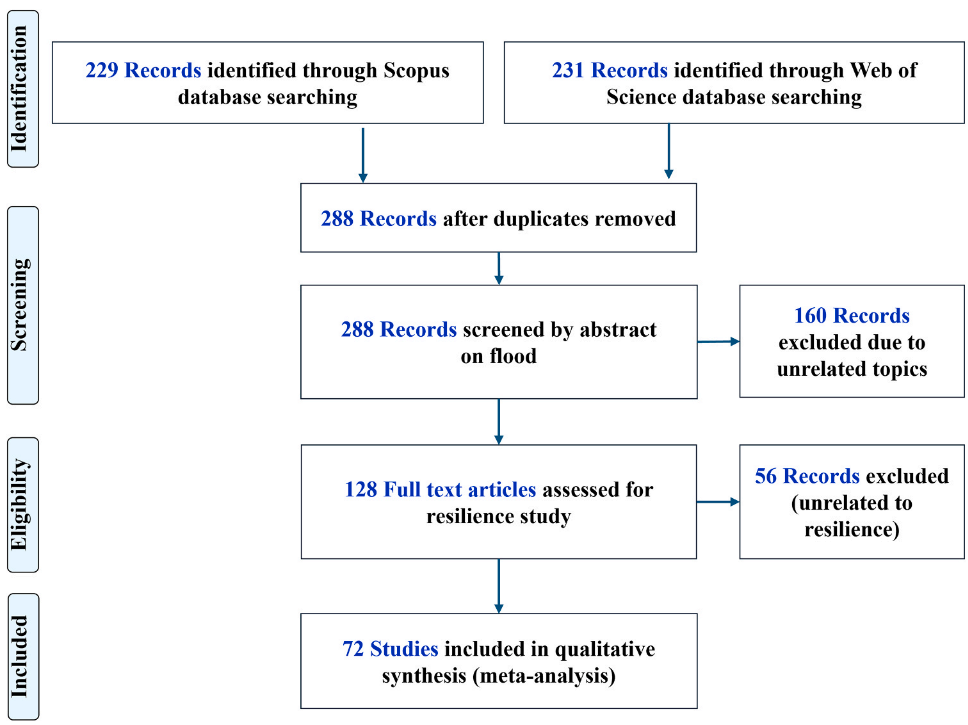

Fig. 3. The flowchart of the PRISMA consortium illustrating the study selection procedure.

For abstract screening criteria, all studies had to involve humans and floods. Ecology-focused topics were excluded, even if they involved floods. Papers addressing only floods or floods combined with other events (e.g., droughts) were included. Papers exploring flood resilience alongside other concepts were also included. Salinity inundation from sea-level rise, but not by drought, was also considered, given its relevance to flood resilience.

For full-text screening, studies on flood resilience were assessed using socio-ecological resilience framework (Zevenbergen et al., 2020) and the nine measure groups proposed by (Yang et al. (2021), covering four themes: (1) central and local governance systems; (2) agricultural, infrastructure and engineering, and early warning and forecasting technologies; (3) family and social networks; and (4) knowledge and culture. Papers could include one or multiple measures (e.g., integrated farming systems such as rice-shrimp farming or lotus-rice farming), so total mentions often exceeded the number of papers. All measures are visualized in Fig. 4, with detailed descriptions in Table 1 and study proportions in Appendix A.

The thematic/content synthesis and analysis method, one of the most typical methods for qualitative evidence synthesis, was chosen as the qualitative methodology (Thomas and Harden, 2008). With a sufficient number of review papers, Excel was used for open, axial, and selective coding, and data meta-analysis. The extracted data on flood resilience measures were statistically analyzed and organized in findings.

3. Results

3.1. Statistical overview of screening records

The initial search strategy in Figs. 5a and b identified 288 journal articles, book chapters, and conference papers from 1999 to July 2024. Of these, 72 papers contained our search terms and were conducted in various countries. Fig. 5a illustrates that flood resilience has been the research focus since 2009. The number of flood resilience-related papers

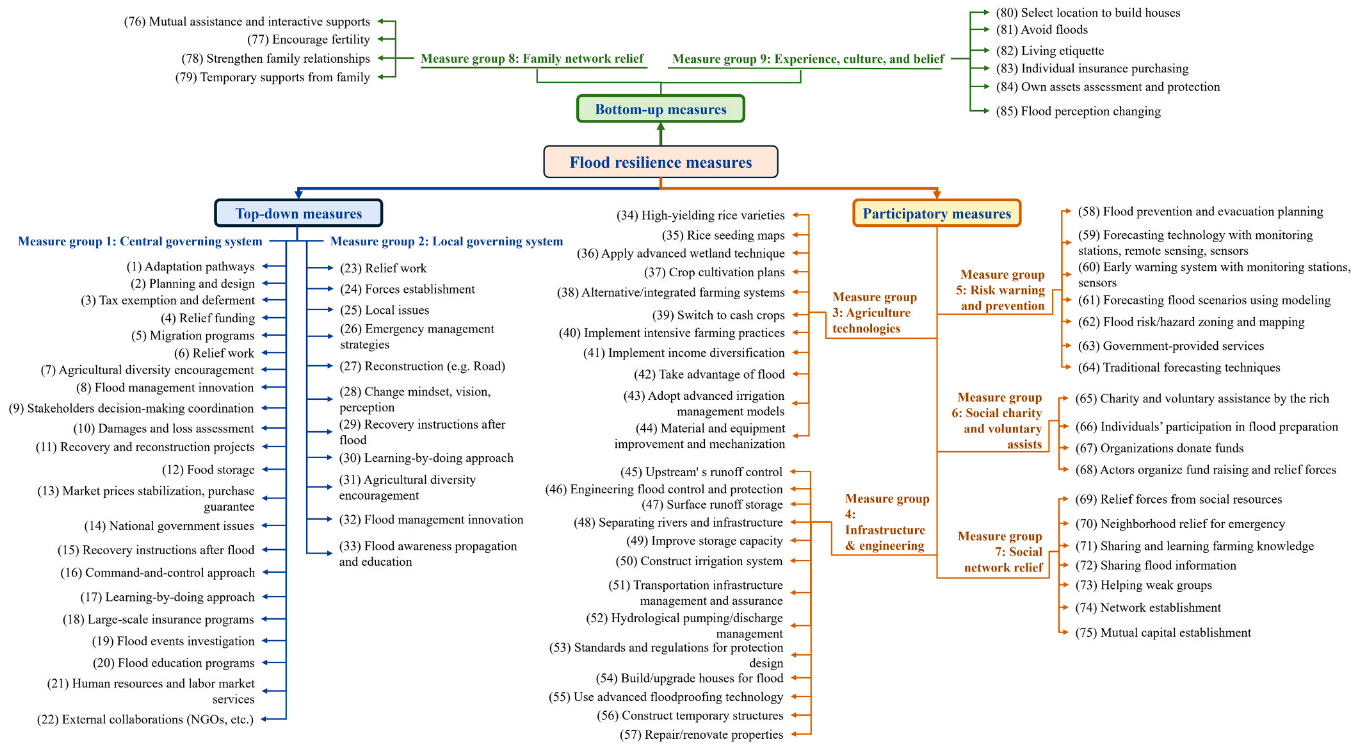

Fig. 4. Eighty-five flood resilience measures, categorized into nine measure groups and three approaches, were referenced for synthesis from (Nguyen and Dang, 2016; Chiang and Ling, 2017; Tran et al., 2019a; Tran, 2020a; Tran and Tuan, 2020; Yang et al., 2021; Tri et al., 2023).

has significantly increased in recent years, with a notable surge in publications from 2018 to 2023. Fig. 5b shows that the majority of the papers focused on the VMD (64 papers - 84.2 %) and Kratie in eastern Cambodia (8 papers - 10.5 %), with only a few studies conducted in other countries: China (1 paper), Thailand (2 papers), and Laos (1 paper). There are no papers examining flood resilience in the entire MRB or in Myanmar.

The reasons for excluding papers are shown in the tag-cloud chart (Fig. 6). The chart shows that a quarter of the excluded studies (55 papers) were due to their focus on other flood-related concepts, such as flood risk, flood hazard, or flood vulnerability. 28 papers were excluded for concentrating on general climate change or other disasters unrelated to floods, whereas 25 papers focused on different geographical locations. More than half of the excluded papers addressed various sectors, such as agriculture (19), ecology (15), and hydrological modelling (16).

3.2. *Distribution of flood resilience measures applied in the Mekong River Basin*

Fig. 7 provides an overview of the proportional distribution of 85 flood resilience measures applied in the MRB. Descriptions of flood resilience measures can be found in Table 1, and the studies referenced, and their proportions can be found in Appendix A. The figure highlights the top five most frequently mentioned measures attributed to engineering flood control and protection measures (46, Measure group 4) with 6.4 % of the total 518 mentions across 72 papers, crop cultivation (37 - Measure group 3) with 5.6 %, flood perception changing (85, Measure group 9) with 5.0 %, alternative farming systems (38, Measure group 3) with 4.2 %, and sharing and learning farming knowledge (71, Measure group 7) with 3.9 % (See Appendix A). There was a significant decline in the number of papers mentioning other measures, and 16 suggested measures have not yet been mentioned in the MRB.

While Fig. 8 presents the proportional distribution of measures across three flood resilience approaches and nine measure groups, Table 2 illustrates the frequency of measures mentioned by the MRB countries. Details of the proportional allocation of each measure in each nation can be found in Appendix A.

Generally, the participatory approach, which involves cooperation between governments and residents, reported the highest proportion at 66.80 % of the total 518 mentions across 72 papers (Fig. 8a). This significantly exceeded the top-down and bottom-up approaches, which accounted for 18.53 % and 14.67 % of total measures, respectively (Fig. 8a).

As shown in Table 2, the included papers were mainly concentrated in Vietnam, Cambodia, and Thailand. Accordingly, the number of papers mentioning measure groups was also highest in Vietnam, followed by Cambodia and Thailand. In contrast, the number of papers mentioning measure groups in other countries was relatively modest. For example, China accounted for only a small percentage in measure groups 2, 4, 7, 8, and 9, while Laos is only in measure group 9. Myanmar was not mentioned in any measure group across the 72 included papers.

3.2.1. *Breakdown of top-down measures*

Fig. 8b highlights the roughly equal responsibility shared between national and local governing systems within the top-down measures in developing strategies and programs to support citizens in advancing flood resilience, 52.08 % and 47.92 %, respectively. In addition, Table 2 shows that top-down flood resilience enhancement measures were mentioned more in research papers in Vietnam than in the other countries, with the rates of 82.14 % and 91.49 %, respectively.

National governments strongly encouraged decentralization in flood management, with stakeholder coordination in decision-making (9) accounting for 12.50 % of top-down measures. States also implemented various programs to enhance their capacity to cope with flooding. Examples include flood management innovations (8) (6.25 %) and flood education initiatives (20) (6.25 %). Moreover, planning and design measures (2), adaptation pathways (1), relief funding programs (4), national government issues (14), and external collaborations (22) each accounted for 4.17 % of the approach.

Local governments also implemented numerous flood support

Table 1
Descriptions of flood resilience measures.

Codes	Measures	Description
I. Top-down measures		
Measure group 1: Central governing system		
1	Adaptation pathways	Adaptation pathways (Adaptation Tipping Point (ATP) scheme, cumulative adaptation, etc.)
2	Planning and design	Planning and design (zoning intervention plans, spatial planning strategies, open spaces, urban morphology, smart cities and intelligent communities, land use and urbanization, and land development)
3	Tax exemption and deferment	Tax exemption and deferment
4	Relief funding	Relief fundings (Prices subsidies, loans, compensation after flood, etc.)
5	Mitigation programs	Government-led population migration programs (managed retreat and Resettlement on living and farming lands
6	Relief work	Relief work (food, protective gear, clothes, etc.)
7	Agricultural diversity encouragement	Campaign of encouraging agricultural diversity
8	Flood management innovation	Innovation in flood management (Mekong Delta Plan 2013, adopting new flood policy from another management system such as Australian, etc.)
9	Stakeholders decision-making coordination	Coordination of decision-making among government agencies, intergovernmental relations, and between government and individuals (decentralized governance, regulation of actors, multi-level network governance, etc.)
10	Damages and loss assessment	Damages and losses assessment
11	Recovery and reconstruction projects	Recovery and reconstruction projects (Help in the reconstruction of roads, homes, irrigation systems, dams, canals, etc.)
12	Food storage	Food storage projects for flood periods
13	Market prices stabilization, purchase guarantee	Market prices stabilization, guarantee the purchase of products (rice, etc.)
14	National government issues	National government issues: Code, Constitution, Resolution, Directive, Decree, Circular, Joint Circular, Decision, and By-law documents to adapt to climate change and floods (e.g. Resolution 120)
15	Recovery instructions after flood	Recovery instruction after flood (overcoming consequences, corrective measures).
16	Command-and-control approach	Command-and-control approach where the governments manage all flood adaptation
17	Learning-by-doing approach	Learning-by-doing approach throughout flood events
18	Large-scale insurance programs	Government-implemented and managed large-scale insurance programs, such as the National Flood Insurance Program (NFIP) in the United States.
19	Flood events investigation	Flood events investigation
20	Flood education programs	Flood education programs provided by the government (e.g. course training, workshop, etc.)
21	Human resources and labor market services	Government-provided human resource services and labor market services
22	External collaborations (NGOs, etc.)	Supports/collaborations with external actors (NGOs, NPOs, Dutch government, Australian government, partners, etc.)
Measure group 2: Local governing system		
23	Relief work	Relief work (food, protective gear, clothes, etc.)
24	Forces establishment	Political and military force establishment to maintain local social stability
25	Local issues	People's Committees at all levels from provinces issue Resolution, Decision to adapt to climate change and floods
26	Emergency management strategies	Emergency management strategies during flood season (local evacuation)
27	Reconstruction (e.g. Road)	Programs to help in the reconstruction of roads, homes, irrigation systems, dams, canals, etc.
28	Change mindset, vision, perception	Change mindset, vision, perception (place themselves to citizens, floods as a friend - 'living with flood', etc.)
29	Recovery instructions after flood	Recovery instruction after flood (overcoming consequences, corrective measures).
30	Learning-by-doing approach	Learning-by-doing approach throughout flood events
31	Agricultural diversity encouragement	Campaign to encourage agricultural diversity/transformation, or flood-based livelihoods (high-tech and organic agriculture, etc.)
32	Flood management innovation	Innovation in flood management (Mekong Delta Plan 2013, adopting new flood policy from another management system such as Australian, etc.)
33	Flood awareness propagation and education	Propagate and educate citizens on flood awareness (hazard and flood adaptation, transforming farming models, sustainable development, etc.)
II. Participatory measures		
Measures group 3: Agriculture technologies		
34	High-yielding rice varieties	Investing in high-yielding rice varieties that can adapt to floods and are resilient to various conditions
35	Rice seeding maps	Build/vary seed maps to comply according with seasons
36	Apply advanced wetland technique	Apply advanced tillage techniques (wetland, ways of using fertilizer, advanced pesticides or fertilizer, etc.)
37	Crop cultivation plans	Crop cultivation plans: Cropping rotations, sequence crops, multiple cropping systems (Rice-Rice-Mungbean, Rice-Maize, etc.)
38	Alternative/integrated farming systems	Alternative/Integrated farming systems (Integrate freshwater aquaculture into crops (rice-fish, rice-shrimp, etc.))
39	Switch to cash crops	Switching more cash crops rather than rice (fruits, sesame, corn, sweet potatoes, etc.)
40	Implement intensive farming practices	Implement intensive farming practice (Small-scale farming, low-dike/high-dike crops farming, etc.)
41	Implement income diversification	Diversify income sources (house renting, informal jobs, etc.)
42	Take advantage of flood	Take advantage of flood (capture wild aquatic sources, wash away saltwater and add nutrients to the soil by discharge into fields, etc.)
43	Adopt advanced irrigation management models	Adopting advanced irrigation management model ('one bund, two ditches', more ponds, etc.)
44	Material and equipment improvement and mechanization	Farming material and equipment improvement and mechanization
Measures group 4: Infrastructure and engineering		
45	Upstream's runoff control	Upstream's runoff control (afforestation, dam and sluicegates construction, etc.)
46	Engineering flood control and protection	Engineering flood control and protection (dikes, dykes, levee, barriers, embankments, sluicegates, etc.)

(continued on next page)

Table 1 (*continued*)

Codes	Measures	Description
47	Surface runoff storage	Surface runoff storage (reservoirs, storage areas, wetlands…);
48	Separating rivers and infrastructure	Separating rivers and residential/ infrastructure (dyke and dike systems to zone and control land use and infrastructure)
49	Improve storage capacity	Improving river storage capacity (creating bypass river sections, deepening, expanding existing river branches)
50	Constructing irrigation system	Irrigation system to retain water in the dry season and prevent water from flowing into fields in the rainy season
51	Transportation infrastructure management and assurance	Management and assurance of transportation infrastructure and the supply systems (Road construction, road improvement, road fixing, etc.)
52	Hydrological pumping/ discharge management	Hydrological pumping/discharge management (Purchase pumping equipment, flood discharge rights, flood regime, etc.)
53	Standards and regulations for protection design	Standards and regulations for the design of flood protection structures are established by the government
54	Build/upgrade houses for flood	Build/upgrade houses suitable for maximum flood levels (build permanent stilt houses, higher floor levels, etc.)
55	Use advanced floodproofing technology	Use advanced floodproofing technology such as dry floodproofing and wet floodproofing of houses, or electricity control system such as water-depth level sensors
56	Construct temporary structures	Construct temporary structures (stilt houses, temporary construction materials, footbridges, etc.)
57	Repair/renovate properties	Repair/renovate their property (houses, fences, farms, etc.)
Measures group 5: Risk warning and prevention		
58	Flood prevention and evacuation planning	Flood prevention and evacuation planning from the government
59	Forecasting technology with monitoring stations, remote sensing, sensors	Forecasting technologies by qualitative analysis on agricultural meteorology conditions with monitoring stations, remote sensing, sensors (anemometers, rain gauges, hydrometers, ground temperature meters))
60	Early warning system with monitoring stations, sensors	Early warning system (heavy rain early warning system, flood early warning system)
61	Forecasting flood scenarios using modeling	Forecasting flood scenarios using modelling (hydraulic-hydrological modeling, etc.)
62	Flood risk/hazard zoning and mapping	Flood risk/hazard zoning and mapping
63	Government-provided services	Government-provided services (rescue force for emergencies, spread flood information via TV, radio, cell phone SMS, etc.)
64	Traditional forecasting techniques	Traditional forecasting techniques (simple phonological observations, solar term understanding, certain weather and harvest forecast)
Measures group 6: Social charity and voluntary assists		
65	Charity and voluntary assistance by the rich	Noble families, wealthy landlords and businessmen, religious leaders, artists do spontaneous charity and voluntary assistance to build public flood shelters
66	Individuals' participation in flood preparation	Individuals actively participated in flood preparation (Red Cross, Flood Response Association, Poverty alleviation activities, policy promotion activities, festival activities, etc.)
67	Organizations donate funds	Influential organizations donate funds (money, food, medical aid, manpower, etc.) to create a public funding for emergency
68	Actors organize fund raising and relief forces	Influential actors organize fast temporary fund raising and arrange and mobilize relief forces (manpower, etc.) for emergency relief and infrastructure construction.
Measures group 7: Social network relief		
69	Relief forces from social resources	Different government-social resources and relief forces integrate to adapt to flood
70	Neighborhood relief for emergency	Neighborhood relief for emergency flood threatening
71	Sharing and learning farming knowledge	Sharing and learning knowledge in farming practices to flood adaptation
72	Sharing flood information	Sharing flood information possessed updates
73	Helping weak groups	Helping the weak in both official and moral matters (the elderly, weak, sick, and disabled)
74	Network establishment	Social network, neighborhood network establishment consolidation, diversification
75	Mutual capital establishment	Establishing/sharing mutual capital/ facilities in flood situations
III. Bottom-up measures		
Measures group 8: Family network relief		
76	Mutual assistance and interactive supports	Mutual assistance and interactive support (manpower, finance, take care of house or children when leaving, etc.).
77	Encourage fertility	Inherit and develop traditional knowledge through generations
78	Strengthening family relationships	Strengthen family relationships and unity
79	Temporary support from family	Borrowing, temporary housing (shelters), and temporary migration to relatives' houses before floods come
Measures group 9: Experience, culture, and belief		
80	Select a location to build houses	Select location to build houses to reduce preliminary flood risk
81	Avoid floods	Avoid floods (evacuate/relocate to other places, believe folk and religious such as Water god worship ceremonies, etc.)
82	Living etiquette	Living etiquette ('Living with flood' if flooded levels are acceptable: floating market, living on boats, etc.)
83	Individual insurance purchasing	Individual insurance purchasing behavior and post-flood compensation.
84	Own assets assessment and protection	Own assessment of assets, protection, and store properties (store grains, save valuables, move vehicles to safe areas, turn off electricity, gas, water supplies, etc.)
85	Flood perception changing	Change flood perception and gain knowledge through self-reflection, learning, and transform abilities into actions

programs. Flood management innovation (32) received the most attention (11.46 %), followed by efforts to shift mindsets and perceptions in flood management (28) (10.42 %). Flood awareness and education (33) (6.25 %) and utilizing a learning-by-doing approach during flood events (6.25 %) were also promoted. Campaigns encouraging agricultural diversity and transformation (31) (5.21 %), along with local Issues (25) (4.17 %), were carried out as part of small-scale flood management strategies.

3.2.2. *Breakdown of participatory measures*

Fig. 8c highlights collaborations between various stakeholders within the social hierarchy. Measure group 3 (agriculture technology) and measure group 4 (infrastructure engineering) were dominant,

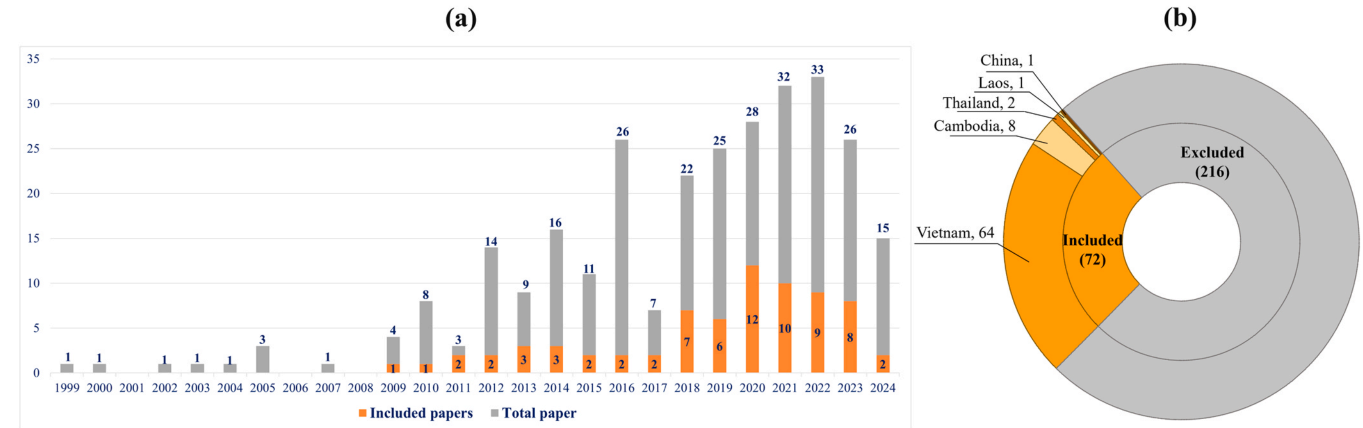

Fig. 5. (a) Number of annual included papers from 1999 to June 2024, (b) Number of included research papers on flood resilience conducted in Mekong River Basin countries from 1999 to June 2024.

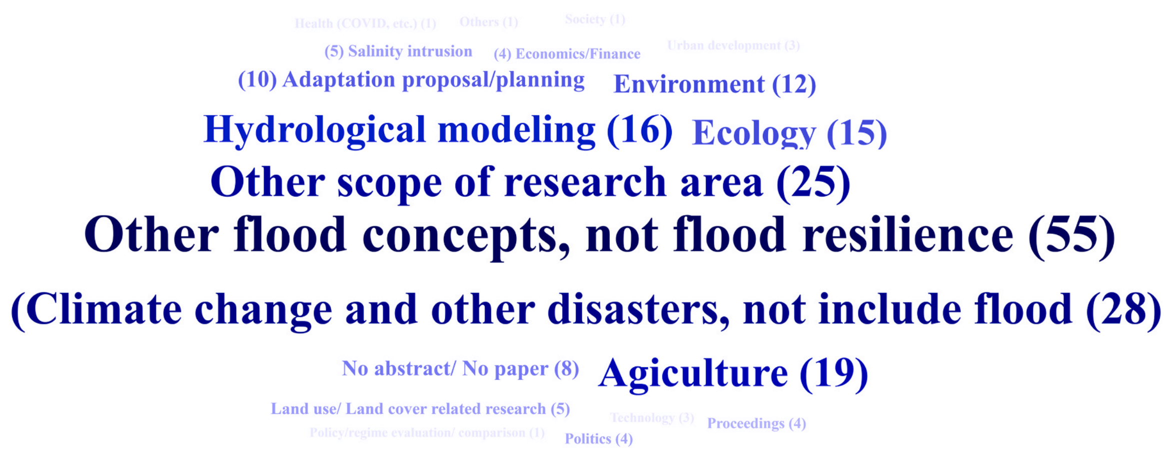

Fig. 6. Tag cloud chart and rationale for excluded papers.

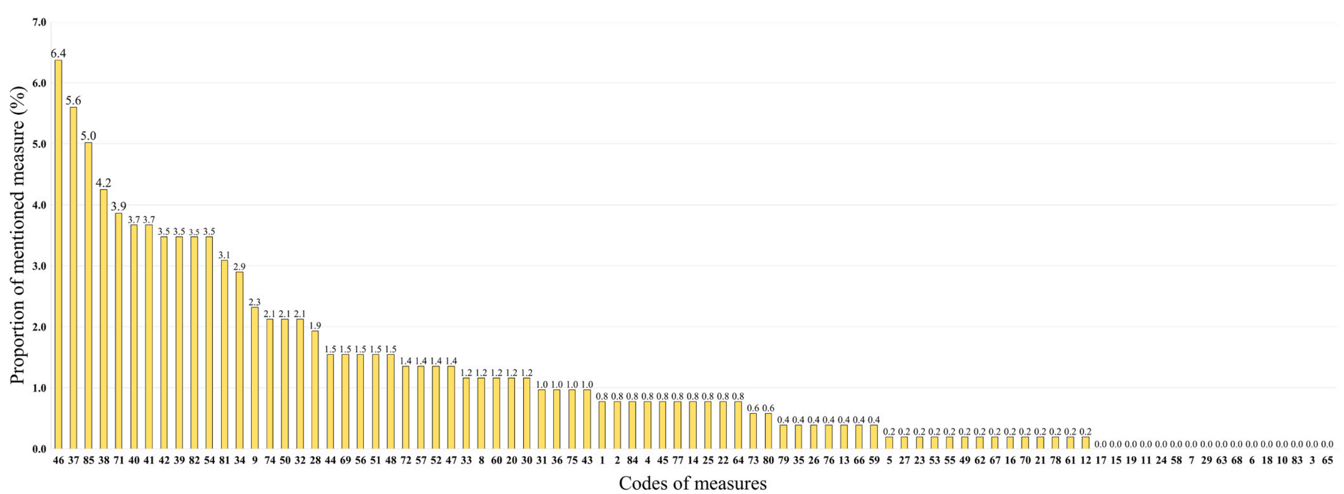

Fig. 7. Proportional distribution of 85 flood resilience measures in the Mekong River Basin.

representing 46.24 % and 32.95 % of the participatory measures, respectively. Among these, Table 2 illustrates that the number of articles mentioning these two groups of measures was significantly higher in Vietnam (84 % and 78.4 %), followed by Cambodia (11.43 % and 14.40 %) and Thailand (4.57 % and 4.00 %). Social network relief (Measure group 7) also played a major role in flood adaptation (15.90 %), with the highest frequency of mentions in Vienam (80 %) (Table 2). Small portions of papers mentioned measure group 5 (risk warning and perception) and measure group 6 (social charity and voluntary assistants), at 2.70 % and 0.58 %, respectively. In both cases, as shown in Table 2, Vietnam accounted for the majority of mentions, with 62.5 % and 66.67 %, respectively, followed by Cambodia with

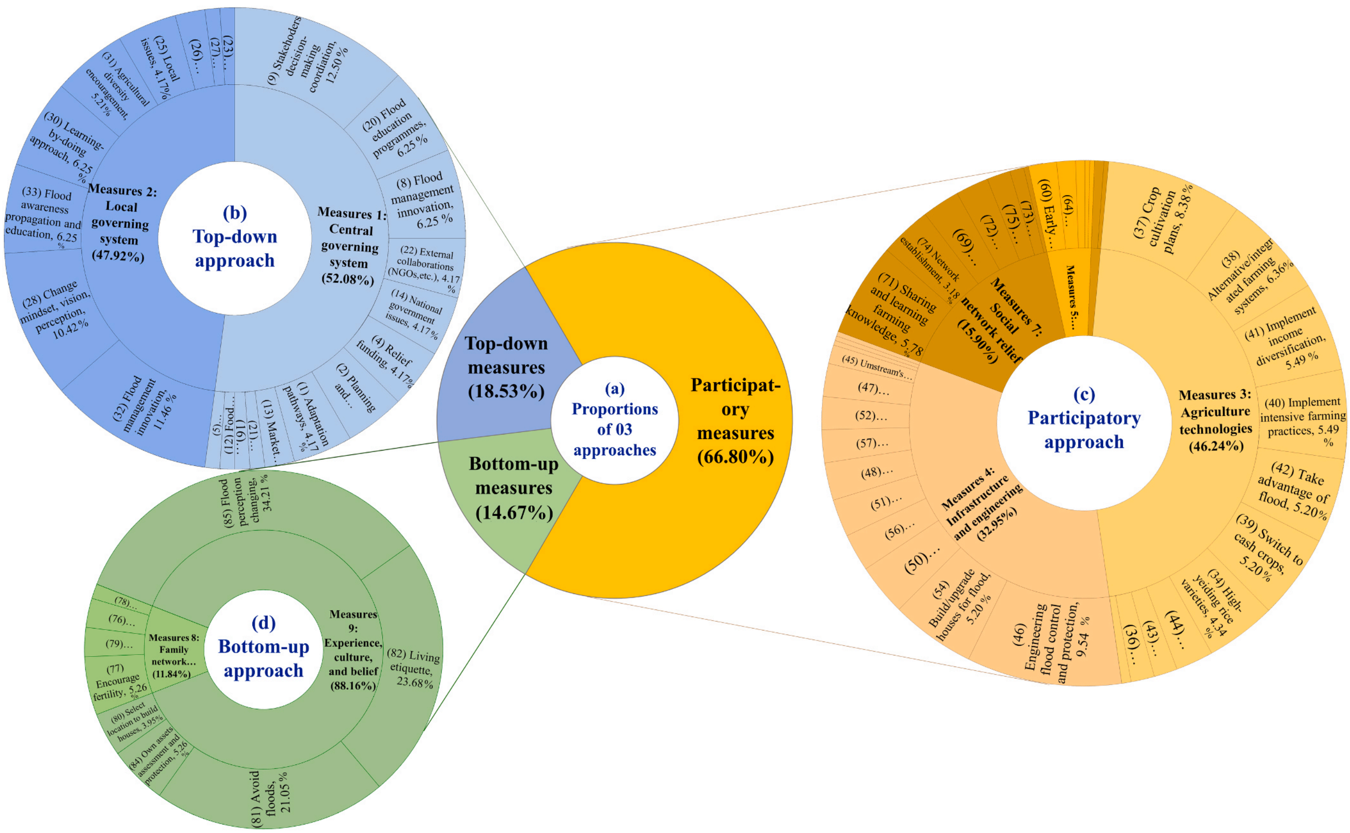

Fig. 8. 85 flood resilience measures categorized to 03 approaches and 09 groups.

Table 2
Proportional allocation of measure groups and proportional share of each country to the measure group.

Level	Measure group	Proportional allocation of measure groups (%)	Proportional share of each country to the measure group (%)						
			China	Myanmar	Laos	Thailand	Cambodia	Vietnam	Total
Top-down (18.53 %)	Measure group 1	9.65	0.00	0.00	0.00	5.36	12.50	82.14	**100**
	Measure group 2	8.88	2.13	0.00	0.00	0.00	6.38	91.49	**100**
Participatory (66.80 %)	Measure group 3	30.89	0.00	0.00	0.00	4.57	11.43	84.00	**100**
	Measure group 4	22.01	3.20	0.00	0.00	4.00	14.40	78.40	**100**
	Measure group 5	2.70	0.00	0.00	0.00	6.25	31.25	62.50	**100**
	Measure group 6	0.58	0.00	0.00	0.00	0.00	33.33	66.67	**100**
	Measure group 7	10.62	1.67	0.00	0.00	5.00	13.33	80.00	**100**
Bottom-up (14.67 %)	Measure group 8	1.74	0.00	0.00	0.00	0.00	20.00	80.00	**100**
	Measure group 9	12.93	2.90	0.00	1.45	0.00	17.39	78.26	**100**
Total		**100**							

31.25 % and 33.33 %.

Specifically, engineering flood control and protection (46) and crop cultivation (37) were the most frequently mentioned measures within the participatory approach (9.54 % and 8.38 %), as well as the total papers shown in Fig. 7. Farmers contributed to agricultural efforts (Measure group 3) alongside governments efforts by altering or integrating various farming systems (38) (6.36 %), switching to cash crops (39) (5.20 %), implementing income diversification (41) (5.49 %), and applying intensive farming practices (40) (5.49 %). They also took advantage of the floodwater (42) to get more income (5.20 %).

Interestingly, to protect their properties, farmers built and upgraded their houses (54) (5.20 %) or constructed temporary structures (56) such as stilt houses and temporary bridges (2.31 %). They also repaired and renovated their properties (57) before and after flood events (2.02 %).

Local governments and experts, in collaboration with farmers, continuously studied and introduced new high-yielding rice varieties (34) (4.34 %). Along with upgrading flood control and protection construction like dams or high and low dikes, the local government continued improving transportation infrastructure and insurance systems (51) (2.31 %) and managed to construct irrigation systems (50) (3.18 %). Governments and local communities established networks (74) (3.18 %), shared flood-related information (72) (2.02 %), and engaged in mutual learning (71) (5.78 %) to enhance flood resilience.

3.2.3. Breakdown of bottom-up measures

Fig. 8d indicates that most papers identified experience, culture, and belief as the main measures within the bottom-up approach, accounting for 88.16 % of the bottom-up measures, with the highest frequency mentions held by Vietnam (Table 2). Locals adapted to floods as part of their daily lives, such as living on boats or trading in floating markets (82) (23.68 %) or avoiding floods (81) through evacuating to other areas (21.05 %). Locals also adapted by changing their perception of floods through learning (85) (34.21 %). Contributing a smaller percentage to this approach, with the highest frequency mentions belongs to Vietnam (Table 2), measure group 8 (family network relief) played a role in flood resilience, including practices such as encouraging fertility (77) (5.26 %) and seeking support from relatives (79) (2.63 %).

3.3. Overlapping of flood resilience measures applied in multiple Mekong River Basin countries

Fig. 9 presents the Venn diagram of the flood resilience measures applied in Mekong River Basin countries. The larger the text, the more frequently the measures were mentioned in the papers. Detailed descriptions of the measures and the referenced papers can be found in Appendix A.

The figure illustrates overlapping measures applied across various countries, while each country adopted unique approaches to improving flood resilience. Vietnam, Cambodia, and Thailand shared the highest number of overlapping measures (11 measures). With a high number of papers focused on Cambodia and Vietnam, these two countries shared a substantial number of mutual measures (23 measures). Vietnam, which was examined in over 84 % of the included papers, has more detailed information compared to other countries, leading to more overlapping and unique flood resilience measures. Due to the lack of papers from Myanmar, there was no evidence of any similar focus between Myanmar and the other countries.

Additionally, the top five most frequently mentioned flood resilience measures from Fig. 7 were found to overlap across at least two countries. Alternative farming systems (38) overlapped among Vietnam, Cambodia, Laos, and Thailand, while flood perception change (85) overlapped in Vietnam, Laos, China, and Cambodia. Engineering flood control and protection (46) and crop cultivation plans (37), the two most frequently mentioned measures, along with sharing and learning farming knowledge (71), were identified as overlapping measures in Vietnam, Thailand, and Cambodia.

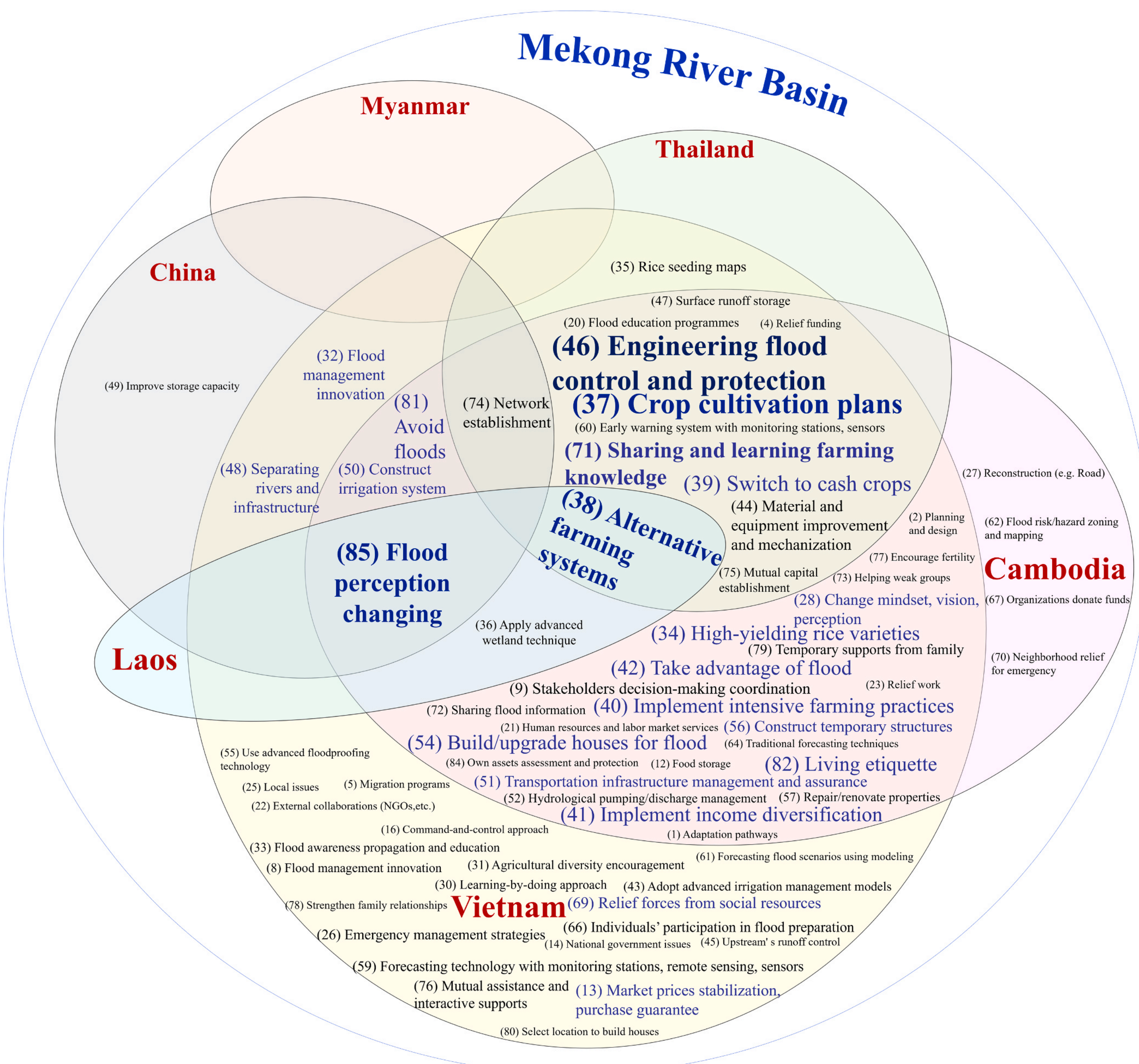

Fig. 9. Venn diagram showing the spatial distribution of measures applied in Mekong River Basin countries.

4. Discussions

4.1. Top three measures commonly applied across most countries

Alternative or integrated farming systems (Measure 38): Due to the agricultural cultures within the MRB (Cramb, 2020), this was one of the most common flood resilience measures highlighted in Vietnam, Laos, Cambodia, and Thailand. Farmers in the VMD explored diversified livelihood strategies, incorporating different farming models to adapt to different flood conditions such as fish farming, particularly freshwater giant prawn culture, in rice fields (Tran et al., 2019a; Almaden et al., 2020), intercropping short-term crops with mangoes (Tran et al., 2019a), combining aquaculture with coconut farming (Tran et al., 2021), integrating lotus with rice, fish and ecotourism (Vo et al., 2021), and raising livestock and cash crops during the food season (Tran and James, 2019). In regions with high salinity, locals utilized shrimp-only farming, rice-shrimp rotations, or salt-tolerant varieties (Mills et al., 2023). Additionally, under Vietnam's "rice first" policy, sluices and dykes encouraged farmers to convert saline water areas into freshwater zones for double-season rice farming (Mills et al., 2023). Similarly, in Laos and Cambodia, farmers integrated rice, livestock or cash crops, followed by fishing during the wet season (Millar et al., 2019; Pal et al., 2023). In Thailand, farmers adopted organic farming practices to enhance local agricultural resilience (Bastakoti et al., 2014).

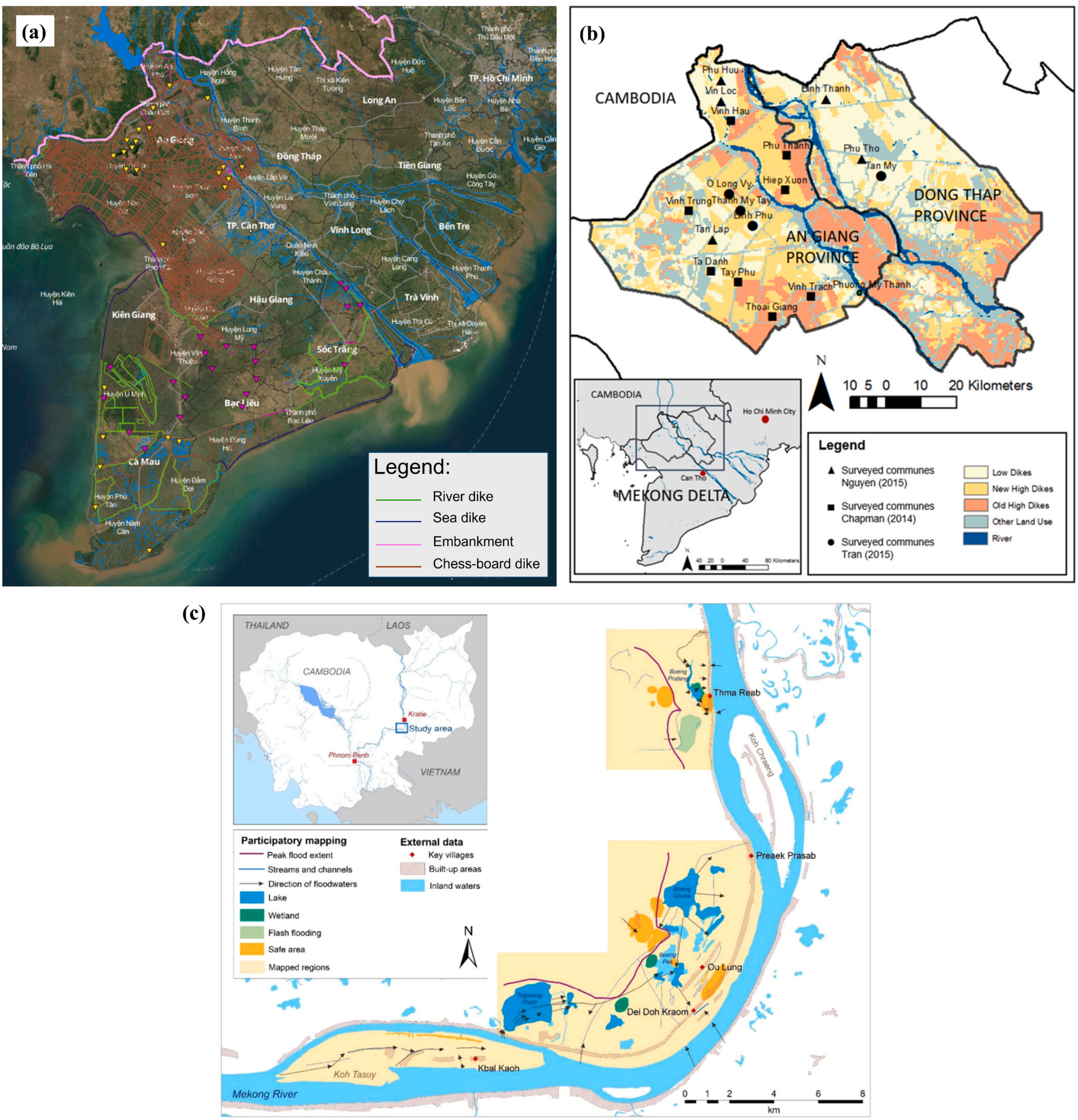

Fig. 10. (a) Engineering infrastructure in the VMD adapted from (MWDB, 2024), (b) High- and low-dike systems in the upper VMD adopted from (van Aalst et al., 2023), (c) Lakes with surrounding levees in Cambodia adopted from (Pauli et al., 2021).

Flood perception changing (Measure 85): The shift in flood perception was reported in China, Laos, Vietnam, and Cambodia. Locals drew on various information sources, such as life experiences, expert or local scientific knowledge, and online resources, for self-reflection, learning, and participation in voluntary education programs, translating this knowledge into adaptive actions for flood resilience (Lun, 2011; Millar et al., 2019; Tran et al., 2022). Especially, farmers transferred expertise from one location to another, adjusting and refining their knowledge through stages of field experiments (Tran, 2020b).

Social network establishment (Measure 74): Although not one of the top five mentioned measures, this measure was also identified as key in China, Thailand, Cambodia, and Vietnam. Farmers in these countries diversified their social and neighborhood networks to access vital social support during flood events or to compensate for other resource shortages (Yang and Andriesse, 2021).

4.2. Top three countries featuring the most frequently mentioned measures

Vietnam, Thailand, and Cambodia were identified as the leading countries applying the most frequently mentioned measures in the MRB:

Engineering flood control and protection (Measure 46): These countries have made significant efforts to finalize their flood management infrastructure along the Mekong River (Thomalla et al., 2018; Pal et al., 2023). In Vietnam, the national and local governments began constructing hydraulic infrastructure in the 1986s, the 1990s and after the flood event of 2000, including high-dike networks covering most rice farms in the delta, with thousands of kilometers of dikes (Figs. 10a and b). Semi-dikes allowing seasonal flooding for double rice cropping were also constructed (Yokoyama et al., 2018; Thomas, 2020; Tompkins et al., 2020). Over 14,000 km of high and low dikes, more than 100,000 km of canals, and many sluice gates formed part of the hydrological engineering projects in the VMD (Tri et al., 2023). Additionally, farmers independently built dikes using the "excavation and filling" method (Nguyen et al., 2020). To protect freshwater rice farming from seawater intrusion, salinity barriers and sluices were also installed in the 1990s (Tran et al., 2019a; Mills et al., 2023). In Cambodia, levees were constructed along lakes through channels perpendicular to the Mekong River, including Boeng Pralang in the north, Boeng Chvea in the central, and Trapeang Thum in the south (Fig. 10c) (Pauli et al., 2021). Thailand built flood embankments along waterways, elevated highways, and barriers surrounding industrial estates, as part of its flood protection efforts (Thomalla et al., 2018).

Crop cultivation plans (Measure 37): Farmers in these three countries adopted crop rotation strategies (37) over the years. The 3–3–2 cropping rotation scheme was dominant in the most VMD areas with high dikes, such as An Giang and Dong Thap provinces. Only double harvests were grown in the third year after applying the triple-crop pattern for two consecutive years (Nguyen et al., 2022; Tang et al., 2022a). In some areas in the upper VMD, one-fifth of farmers rotated crops, such as sweet potatoes and chilli, during the dry season (Ho et al., 2022; Palazzo et al., 2022). In salinity-prone coastal areas of the VMD, rice was grown in the Dong-Xuan (Winter-Spring) season following salinity surges (Mills et al., 2023). Cambodian farmers also prioritized a two-crop rotation of rice and maize per year. Wet rice and wet maize were grown during the monsoon season, with planting dates adjusted to the onset of rains, typically in May. Dry rice and dry maize were planted after the floodwaters receded, relying on irrigation and moisture retained in clay-rich soils (Henningsen et al., 2021; Pauli et al., 2021). Cambodian farmers also cultivated two mango trees using specialized methods (Pauli et al., 2021). In Thailand's Na Khu area of Kalasin, farmers cultivated various crops such as cassava, beans, and corn during the dry season after harvesting rice (Bastakoti et al., 2014).

Sharing and learning farming knowledge (Measure 71): Locals of these three countries also focused on sharing and learning from one another (71) through informal meetings, such as at the cafés and house visits, and through formal meetings, such as at referendums (Tran, 2020b; Pham and Ngo, 2023).

The overlaps in flood resilience measures among the lower MRB countries, as well as the limitations in publications and measures in China, Myanmar, and Laos can largely be attributed to decentralization policies, along with three other factors: shared cultural backgrounds, historical development, and environmental context:

Decentralization policies: The implementaion of the policies assign administrative and financial responsibilities to local authorities, especially at the provincial level, creates a decentralized setting for flood governance in most MRB countries (Kurauchi et al., 2005; Fritzen, 2006; Yena and Kanyara, 2024).

Cultural and historical similarities: Migrants from southern China, especially Guangxi and Yunnan, migrated southward with their common Daic or Tai-speaking origins from the first millennium CE (Baker, 2002; Stuart-Fox, 2006). They introduced rice farming traditions and water management techniques, including bunded and terraced paddies, well-suited to floodplains. These practices shaped local livelihoods and fostered cultural and environmental adaptation similarities across the MRB (Cramb, 2020).

Environmental context: In China, the Lancang River lies mostly outside the MRB. Only a short stretch near the border with Myanmar is part of the MRB, accounting for a very small portion of the MRB, while Myanmar's share is just 4 %. (MRC, 2005; Baiyinbaoligao et al., 2020; MRC, 2022). Consequently, flood hazards and related research are limited in both countries, with little focus on engineering-based flood control and protection, and crop cultivation planning in these areas. In Laos, the Mekong River flows mainly through hills and plateaus at elevations of 1000–2000 m, which cover up to 85 % of the country and may partly explain the limited research conducted there (Baiyinbaoligao et al., 2020). By contrast, the lower MRB, covering Thailand, Cambodia, and the VMD, makes up the largest share of the basin, is heavily influenced by the monsoon rains, and faces recurrent flooding (Cosslett and Cosslett, 2017; Baiyinbaoligao et al., 2020). Hence, both governments and residents in these regions have made substantial efforts to adapt to and transform to improve engineering and adaptive capacities.

4.3. Special flood resilience measures in the Mekong River Basin

4.3.1. The Vietnamese Mekong Delta

Located at the lower part of the Mekong River and covering 9,3 million hectares, the VMD is the region most impacted by both freshwater and seawater flooding (Vu and Truong, 2021). However, over the years, locals in the region have improved their flood resilience capacities through various efforts.

Decentralization in flood management has been strongly encouraged since the Innovation period (Đổi Mới) in the VMD, through initiatives such as adaptive flood governance (Tran and James, 2019; Tran et al., 2020) and adaptive co-management (Tran et al., 2019b), where stakeholders coordinate decision-making. Moreover, planning and design measures, such as zoning for lotus farming (Vo et al., 2021), land-use planning (Thomalla et al., 2018), and adaptation pathways like Adaptation Tipping Point (ATP) schemes (Radhakrishnan et al., 2018) and cumulative adaptation (Yang and Andriesse, 2021), were applied in the region. Various programs to enhance flood resilience were also introduced, especially the Mekong Delta Plan 2013 (Tran et al., 2019b; Tang et al., 2022a; Tri et al., 2023).

At the national level, several Issues were released, including Vietnam's Resolution 120 (Tang et al., 2022b), laws (Tran and James, 2019; Tran, 2020a), and Decisions (Tri et al., 2023) for flood management strategies. Relief funding programs, including financial support (McKinley et al., 2021), loans (Vo and Mushtaq, 2011; Brown et al., 2018), and compensation after floods (Thomalla et al., 2018)) were also introduced to support affected citizens. The government further enhanced external collaborations, forming partnerships with the Dutch and Australian governments (Tran and Tuan, 2020).

At the local government level, numerous flood support programs were implemented. Innovations such as North Vam Nao scheme adopted from AusAID (Tran and Tuan, 2020; Tran et al., 2021) and adaptive learning practices (Tran et al., 2019b) were introduced. This was accompanied by a shift in mindsets and perceptions in flood management, emphasizing empathy with citizens (Tran and Rodela, 2019) and adopting a 'living-with-flood' approach (Vo and Mushtaq, 2011; Thomalla et al., 2018). Local governments also promoted flood awareness and education through training sessions or workshops within communities (Tran, 2020b; Tran et al., 2021), awareness-raising campaigns (Do et al., 2016), and a learning-by-doing approach during flood events (Tran, 2020b; Palazzo et al., 2022). Campaigns encouraging agricultural diversity and transformation, such as high-tech and organic agriculture (Tran and James, 2019; Vo et al., 2021), along with local initiatives and Decisions (Tran, 2020a; Tran and Tuan, 2020), were carried out as part of small-scale flood management efforts.

4.3.2. *Unique measures applied in China and Cambodia*

As an upstream nation of the Mekong River with large reservoirs, Chinese citizens and the government cooperated in constructing and upgrading water storage capacity (Lun, 2011). Also, private ferry operators or islanders in Cambodia worked to repair roads, culverts, levees, bridges, and wells before and after floods (Williams et al., 2021). The government used remote sensing methods and leveraged local knowledge to identify areas which were at risk of flooding, prioritizing them for irrigation and protection plans (Pauli et al., 2021). Donations from organizations, supported by charitable grants, were also mentioned in Cambodia, along with neighbors helping each other to repair damaged homes (Sok et al., 2011).

4.4. *Gaps in flood resilience measures application in the Mekong River Basin*

As shown in Fig. 7, approximately 16 measures were suggested for flood resilience analysis, but these were not mentioned in the included papers. There could be some possible explanations as below.

Most of the measures omitted in the included papers belong to Measure group 1, which involves actions by the national government due to the decentralization policies. As a result, projects for agricultural diversity encouragement (7), recovery and construction (11 and 15), learning-by-doing strategies (17), and relief work (6) were primarily carried out in the flood-affected areas, which fall under measure group 2.

Although not specifically discussed in the papers, the national government continued to implement relief, evacuation, and flood recovery guidance whenever a flood occurred through official dispatches and resolutions. Notable examples include the Government Resolution No. 15/2000/NQ-CP in 2000 or the Decision No. 2137/QD-TTg in 2011, which directed relief, evacuation, and recovery efforts for the historic 2000 flood in the VMD (Nguyen, 2002). However, since the 2000 and 2011 flood events, extreme floods have not occurred in the VMD, only annual floods, which people are accustomed to and know how to manage with established flood coping measures (Tran et al., 2024). Therefore, emergency relief from local governments has been less necessary. Instead, as the research articles indicate, government funds and efforts have focused on enhancing the capacity to respond to annual floods through engineering and social actions.

Damage of loss assessments (10) are typically conducted by the national government or academic institutions with the capacity to collect data, analyze, and make recommendations. However, because the research question focused on flood resilience, papers such as (Wassmann et al., 2019; Nguyen et al., 2021; Sok et al., 2021) solely addressing flood risk assessment were skipped and excluded from this study. This is why the measures related to damage and loss assessment were not included in the paper reviewed.

Some gaps remain and should be considered, particularly regarding measures applied in the other countries that could be recommended for the MRB countries. For example, tax exemptions and deferments (3), a relatively useful approach in global flood management, have been implemented in countries like Korea (Oh, 2022) and Brazil (Pompeu and Vilpoux, 2023). The reason MRB countries have not adopted this measure is due to their status as developing nations. In these countries, taxes are crucial for government funding economic growth, especially in relation to income growth (Chelliah, 1971).

Flood insurance programs (18), such as the National Flood Insurance Program (NFIP) in the US (Michel-Kerjan et al., 2012), Slovakia (Solín et al., 2018), France and the UK (Crichton, 2008) have proven effective and could serve as models for the MRB. A possible reason why MRB countries have not yet adopted this approach could be the lack of a sufficiently large public budget to support such insurance programs. For Vietnamese farmers, for example, agricultural flood insurance is new (Nguyen et al., 2019). A very small percentage (0.015 %) of all insurance earnings comes from agriculture insurance, according to Vietnam's Ministry of Finance (Nguyen et al., 2019). Although agricultural insurance was first introduced in 2011, it is currently in the experimental stage for a variety of reasons (Nguyen et al., 2019). However, agricultural flood insurance has a potential market, and by growing the insurance industry, the governments might lessen the cost of disaster assistance subsidies (Nguyen et al., 2019).

4.5. *Trade-offs of available measures and proposals for flood resilience development in the Basin*

Many studies have shown that human intervention in the hydrological processes of the Mekong River, along with climate change, has introduced numerous stressors to the MRB, especially environmental issues (Pokhrel et al., 2018; Nguyen et al., 2020; Tran et al., 2022).

The construction of dams has seriously altered the hydro-sedimentary regimes of the MRB (Dinh et al., 2012; Hoang et al., 2023). As a result, reduced downstream water flow has limited the deposition of alluvium in double-crop rice fields (Hoang et al., 2023). In addition, the decreased water volume has caused engineering systems to underperform, as water level consistently falls below design expectations, increasing the risk of landslides (Phung et al., 2021).

Another trade-off related to high-dike construction is the increased risk of downstream flooding. Many studies have demonstrated that over-construction of high dikes upstream contributes to this risk, particularly in the VMD (Marchand et al., 2014; Fujihara et al., 2016; Tran et al., 2018).

Hence, some potential proposals for sustainable flood resilience strategies in the MRB were developed across the MRB:

Agricultural and irrigation roadmaps: Hoang, H.M. et al., (2023) designed these two solution roadmaps using the Dynamic Adaptive Policy Pathways (DAPP) technique, aiming to sustain rice production in the flood-prone areas in the VMD beyond 2030 while considering unpredictable changes in surface water supplies.

New urban model: Do et al. (2024) also proposed a new urban model in Cao Lanh city, Dong Thap province, Vietnam, featuring a core city and three peri-urban centers as agricultural and service hubs. Emphasizing ecological knowledge, the design addresses flooding, landslides, and saltwater intrusion while revitalizing local ecology and preserving traditional lifestyles to foster sustainable growth.

Holistic approach to coastal approach: Tamura et al. (2018) suggested the approach, including mangrove conservation, saline adaptation, and labor-based flood-proofing using local resources like jute, to counter wave erosion and protect high-risk areas.

Dynamic resilience pathway: Garschagen et al. (2011) introduced the pathway focused on "small-scale tipping points" for integrative governance. By emphasizing household-level resilience, the framework helps clarify cause-effect relationships, responsibilities, assess capacities, and implement concrete solutions.

All practical studies on flood resilience were conducted independently within each country, with no cross-country comparison. Yet, as Mekong nations are both interconnected geographically and share similar development paths, there are significant opportunities for collaboration. A unified flood management framework could strengthen resilience across the MRB.

5. Conclusion

5.1. Research findings and recommendations

The purpose of the study is to generate a comprehensive understanding on flood resilience as developed by people in the MRB to improve their capacity to cope with flooding. Throughout this systematic review, we have identified several key findings.

First, this study has found that research on flood resilience has emerged and intensified in recent years, with a particular focus on the MRB.

The statistical analysis indicates increased cooperation among stakeholders, rather than strictly top-down or bottom-up actions, in Mekong River Basin countries. Decentralization or coordination led to the participatory approach, and agricultural technologies and infrastructure-engineering improvements were the focus of both governments and citizens of these countries to enhance their resilience. Bottom-up actions, such as social network relief, social learning, changes in local knowledge and awareness, and local experience and culture, also contributed to improved resilience.

There are various overlaps in flood measures across MRB countries, particularly between Vietnam and Cambodia, and with Thailand, Laos, and China. The finding supports the idea that, with shared cultural backgrounds, historical development, and environmental context, people in these countries had similar experiences and knowledge related to flood adaptation, despite geographic differences. However, each country still had their unique methods for improving their flood resilience capacity.

Due to the interconnection among countries along the Mekong River, this study highlights the need for a large, collaborative study across these countries to examine the entire Mekong region on both spatial and temporal scales. Such a study would provide critical insights into the region's flood resilience context, enabling countries to identify overlaps and diversities in their flood measures and work collaboratively toward Sustainable Development Goals (SDGs).

5.2. Limitations and future research

We acknowledge the potential for bias from using Scopus and WoS. While both are high-quality databases, they primarily index English-language international journals, which may exclude domestic publications or grey literature and introduce geographical or source-related bias, limiting comprehensiveness. More studies on local policy and resilience practices are needed in the future.

We also acknowledge that relying on these databases led to a focus on the lower MRB, which floods more frequently than the upper MRB, emphasizing Vietnam, Cambodia, and Thailand. However, our analysis only considered the frequency of reported measures, more articles from one country may raise frequency of reported measures but not their effectiveness. To avoid skewing, we treated implementation of the measures as equal across the countries.

We also recognize methodological bias due to subjectivity in the screening process. Given the volume and diversity of studies, only selected examples across multiple countries were highlighted. As a result, some less-documented countries may have relevant measures not captured in our analysis.

Another limitation involves overlapping or missing measures across MRB countries, influenced by policy frameworks and cultural contexts. Further research is needed to examine how policy linkages shape resilience strategies over time.

To address the limitations mentioned, future research should include more fieldwork (empirical research) to gather missing data on flood resilience measures, policies, and cultural contexts, and compare it with existing knowledge. This could involve interviews with residents, experts, and leaders, as well as analysis of local documents (e.g. historical and management records) to provide a more complete picture of flood resilience.

CRediT authorship contribution statement

Thanh Phuoc Ho: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Liang Emlyn Yang:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Van Pham Dang Tri:** Writing – review & editing, Supervision, Resources. **Matthias Garschagen:** Writing – review & editing, Supervision, Resources.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Liang Emlyn Yang reports financial support was provided by European Research Council (ERC). Thanh Phuoc Ho reports financial support was provided by German Academic Exchange Service (DAAD). If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2025.104228.

Data availability

Data will be made available on request.

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