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The Role of National Laws in Managing Flood Risk and Increasing Future Flood Resilience

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Abstract: Flood risk is increasing across the world due to climate change and socio-economic developments, calling for a shift in flood risk management (FRM) from post-event activism towards forward-looking planning through an anticipatory resilience approach. Despite advances in flood risk sciences and growing understanding of risks and drivers, the overall governance of flood risk remains a highly reactive process. In this study we explore the role of national laws in determining the nature of FRM, in particular, the ability to increase flood resilience in the context of climate change. We analyse evidence from the “Climate Change Laws of the World” and “Disaster Law” databases and underpin this with case studies to gain insights on the interplay between national laws and resilience processes. The analysis of 139 laws from 33 countries shows the reactive nature of law-making for flood risk with a clear lack of consideration of future risks. We find (1) a shift in the policy area of flood-related laws from solely water and natural resource management laws into a combination of multiple laws dealing with flood risk e.g. Disaster Risk Management (DRM) and climate change laws, (2) a significant lack of climate change recognition in laws regulating decisions and actions for future flood risks, especially in DRM laws, 3) a prevailing focus on the response and recovery strategies and lack of recognition of risk reduction strategies and proactive flood risk governance approaches, and (4) a large focus on the physical and human capital of flood resilience and less on natural capitals in the national flood laws.

Keywords: national laws, climate change adaptation, disaster risk management, resilience, flood risk

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1. Introduction

Floods affect more people around the world than any other hazards (UNISDR, 2015, Aerts et al., 2018, Hanger et al., 2018). In many places across the world risk levels are increasing, with climate change and socio-economic developments influencing risk patterns and exposure (Nicholls et al., 2008, IPCC, 2018, de Moel et al., 2011). Particularly for many low-lying parts of the world the flood prospects look daunting given the interplay of sea-level rise, changing rainfall patterns and continued urban development in high-risk areas (Kulp and Strauss, 2019). However, flood risks are no longer limited to the usual ‘hot spots’ along rivers or coastal lines: surface water flooding is a growing concern for many settlements—where heavy rainfall poses significant challenges to existing drainage structures, or rain-induced landslides and flash-floods. In the face of these threats a rethink is required, moving from a defence and protect mentality towards a broader resilience approach that employs a variety of strategies and measures to reduce and manage risks, including land-use, spatial planning and natural flood risk management measures (Dieperink et al., 2016).

Forward looking risk reduction and climate adaptation are, thus, important in building resilience of individuals, businesses, and governments to the impacts of extreme weather and long-term changes. The economic case for proactive management of these risks and for avoidance of further risk creation is strong (Mechler, 2004, Mechler, 2016, Shreve and Kelman, 2014). Building climate resilience, therefore, needs to be an essential component of current and future development planning to ensure that previous gains in poverty reduction and economic prosperity are not wiped out by adverse climatic impacts (Surminski et al., 2016, Surminski et al., 2019). The concept of resilience has received significant attention recently, becoming a widely recognized part of the most relevant public and private initiatives on climate risks (see for example UNISDR’s Sendai Framework, Rockefeller’s 100 Resilient Cities initiative or the Coalition for Climate Resilient Investments.) In parallel there has been substantial discussion on the meaning, nature, and implications of resilience in the literature (Schipper and Langston, 2015, Bahadur et al., 2010, Béné et al., 2012) including its shifting conceptions from “bounce back” to “bounce forward” (Peel and Fisher, 2016) and also how to measure it (Keating et al., 2017).

However, what is less clear is whether existing flood risk management regulatory approaches are being adjusted or extended to incorporate a forward-looking resilience approach. While more and more decision-makers recognize the importance of resilience as a concept the management of flood risk remains a very reactive process, still largely driven by post-event activism rather than strategic and forward-looking planning (Surminski and Thieken, 2017, Tingsanchali, 2012). One area that remains still largely unexplored is the influence of laws on the nature of FRM, in particular, the ability to increase flood resilience in the context of climate change. This paper aims to provide insight on the role of national flood legislation in regulating and encouraging current and future flood risk and resilience for communities¹.

The formal legislation system of countries play an important role in setting out rules and frameworks for flood risk governance. These tend to regulate (prohibit, obligate or permit) flood-related decisions, actions and responsibilities. National level laws² are employed to support the integration and coordination of local and national disaster risk management practices and the proper distribution of resources among

¹ Zurich Flood Resilience Alliance defines community flood resilience as “*the ability of a system, community or society to pursue its social, ecological and economic development goals while managing its disaster risk over time in a mutually reinforcing way*” (Keating et al., 2017).

² Legislation or law is a system of rules passed by and enacted by a legislature or other governor body.

different sectors and institutions. Moreover, they create specific accountabilities and liabilities for public officials, private sectors and societies in terms of FRM activities (Alexander et al., 2016a). As such, national flood laws can play a significant role in shaping how flood risks are managed. For example, Arnold (1988), Hartmann and Albrecht (2014), England (2019), Spray et al. (2009), and (Howarth, 2002) look at the influence of national laws on the trends of FRM in the USA, Germany, Australia, Scotland, and England and Wales, respectively. There are also legal studies on other sectors related to flood e.g. national water laws (Van Rijswick et al., 2012, Hobbs Jr, 1997, Howarth and McGillivray, 2002) and environmental laws (Thornton, 2018, Stallworthy, 2006) (Howarth, 2017). However, most of such studies are fragmented, limited in scope and country-specific, and therefore, what seems lacking is a global overview of the flood-related national laws across various countries.

The closest global legal studies that cover some aspects of the flood legislations are those focusing on *Disaster Risk Management (DRM)/Reduction (DRR)* and *climate change adaptation* which has mainly emerged over the last two decades (Thomalla et al., 2006, Mercer, 2010). Such studies have been accelerated by the key international agreements: 1) the Hyogo framework in 2005 and the Sendai framework in 2015 focusing on DRR targets and priorities, and 2) the Paris agreement in 2015 focusing on a set of climate change mitigation and adaptation objectives. For example, the Red Cross and Red Crescent Societies (IFRC) and the United Nations Development Programme (UNDP) have jointly assessed the DRM laws of 31 countries and identified the factors that have supported or hindered the implementation of 'DRR' activities within these laws (IFRC and UNDP, 2014). Moreover, the question about forward-looking laws and policies, and recognition of climate change has offered a new perspective to study risk governance: Averchenkova et al. (2017) and Nachmany et al. (2017) studied the climate change laws of the world and showed a twentyfold increase in the number of national climate change mitigation and adaptation laws (from 60 laws in 1997 to over 1,300 in 2017). However, these studies illustrate the lack of integration of climate change laws into mainstream development strategies of the countries analysed. Olazabal et al. (2019) presented the most up-to-date database of the climate change adaptation policies at national, regional/state and local level across 68 countries and 136 coastal cities. Their analysis showed that coastal adaptation legislation is relatively recent and is concentrated in more developed countries.

There is also growing research on reviewing the local climate adaptation policies and the influence of national climate policies on local/urban level strategies. Heidrich et al. (2016) analysed climate change policies of 200 cities across 11 European countries and found that the number of cities with mitigation and adaptation strategies is larger in countries where a national law requires municipalities to prepare urban climate strategies. Reckien et al. (2018) also analysed the local climate plans of 885 European cities and showed that cities in European countries with national climate legislation are five times more likely to produce local adaptation plans, compared to those cities in countries without such legislations.

Despite all these studies there is still very little evidence on the role of national legislations in enabling or hindering decisions and actions to build flood adaptation and resilience. In this paper we address this knowledge gap by investigating the following three research questions:

- 1) What are the types of national laws currently used to shape and influence FRM, what are their objectives and focus areas, which mechanisms are used, and who do they target?

- 2) How do laws capture the temporal challenges of FRM, particularly, the changing risk levels due to climate change, and are the laws designed reactively or proactively focusing on the post or pre-disaster aspects?
- 3) What roles do the national laws play for community-level resilience, given that FRM and adaptation action need to be local?

To obtain insights on these questions we have collected and analysed the national laws of 33 flood-prone countries and underpinned this with expert interviews and household surveys conducted via the Zurich Flood Resilience Alliance (ZFRA, <https://floodresilience.net/>)³. One should note that this analysis does not aim to evaluate the quality of laws nor the implementation of the laws' regulations. Rather, it tends to provide an insight on how the notions of adaptation and resilience can be applied in the national level legislation mechanisms to influence decision making for flood risk reduction.

This paper is structured as follows. Section 2 describes the methodology and framework used in this study, while section 3 elaborates on the results of the law analysis in three sub-sections corresponding to the three research questions of this paper. Finally, section 4 discusses the main outcome of this study and concludes.

2. Methodology

A mixed-methods approach has been used in this study. As the first step, we collected a dataset of the national laws in 33 countries in collaboration with the "Climate Change Laws of the World" group⁴ in London School of Economics (LSE) and "Disaster Law"⁵ group in International Federation of Red Cross and Red Crescent Societies (IFRC). The resources used for the data collections and methodology used for the selection of relevant laws are explained in supplementary A. Then we conducted an overarching desk-study and content analysis of laws collected and validates them with the local expert knowledge⁶. This method has been used for analysing research questions one and two. The detailed methodology for the text analysis of laws is explained in supplementary A.

Countries have been selected based on three criteria: 1) top 10 countries in terms of the population exposed to *river* flooding, 2) top 10 countries in terms of the population exposed to *coastal* flooding, and 3) the countries identified as the vulnerable countries to flooding in the ZFRA. These selection criteria led to a set of 28 countries. Additionally, to represent a distribution of countries with a different socio-economic development background, we added five OECD countries that have recently been subject to

³ ZFRA is a multi-organizational collaboration between research, private company (Z Zurich Foundation) and non-governmental organizations focusing on finding practical ways to help communities strengthen their resilience to flood. Alliance partners International Federation of Red Cross and Red Crescent Societies (IFRC), Plan International, Mercy Corps, and Practical Action kindly provided their local contacts and expertise to this paper.

⁴ A research group in Grantham Research Institute on Climate Change and the Environment at the London School of Economics (<https://climate-laws.org/>) collecting and maintaining a database covering all laws and policies that are relevant to climate change and have been passed by legislative branches or published by executive branches, and that no longer in draft form. More detail about the types of documents: <https://climate-laws.org/cclow/methodology>.

⁵ Collecting and analysing an online database on the laws related to disaster risk management across the world <https://www.ifrc.org/en/publications-and-reports/idrl-database/>

⁶ Via the local expert (in either flood risk management or climate/disaster laws of various countries) in ZFRA alliance and IFRC team.

flood risk governance analysis under the EU’s STARFLOOD project—Belgium, France, Sweden, Poland STARFLOOD (2016))—and an ongoing flood risk governance investigation by the Geneva Association—Canada. The full list of the 33 countries and their selection criteria can be seen in figure 1 and Table 1.

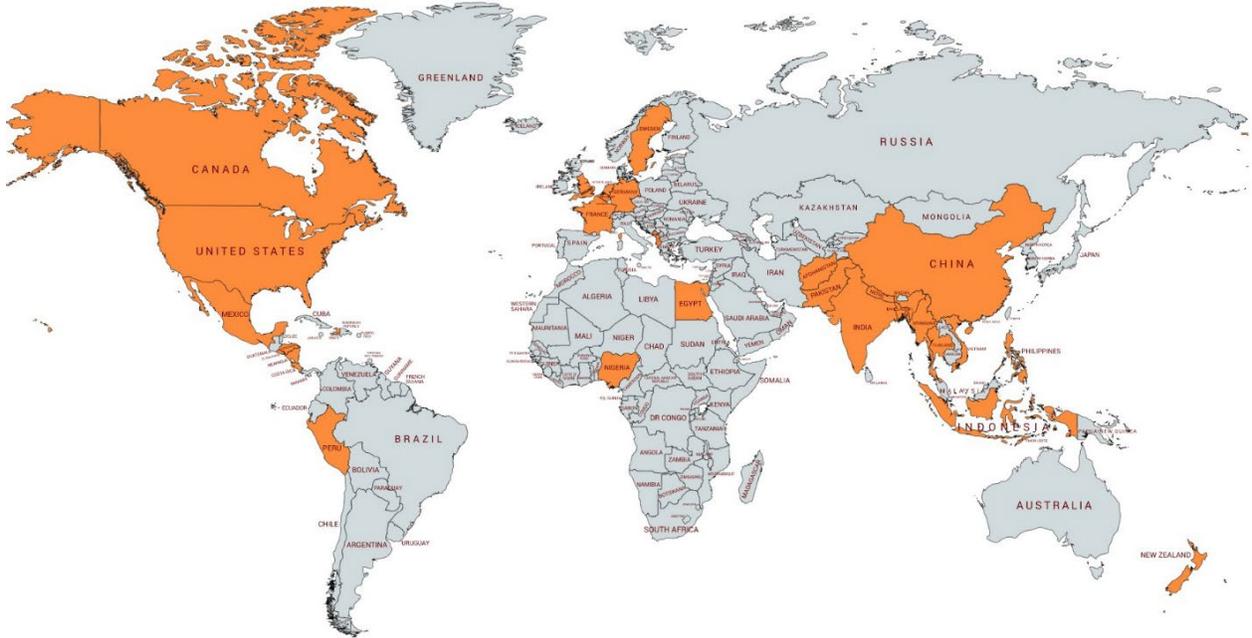


Figure 1: Geographic distribution of 33 countries across the world.

Table 1: 33 countries and the selection criteria for each country

Name of countries	ZFRA countries	Top 10 countries with population exposed to river flooding as per Aqueduct Global Flood Analyzer	Top 10 countries with population exposed to coastal flooding as per Climate Central	OECD countries analysed in the EU and global studies
1. Afghanistan	X	X		
2. Albania	X			
3. Bangladesh	X	X	X	
4. Belgium				X
5. Canada				X
6. China		X	X	
7. Costa Rica	X			
8. Egypt		X		
9. El Salvador	X			
10. France				X
11. Germany	X			X
12. Haiti	X			
13. Honduras	X			
14. India		X	X	
15. Indonesia	X	X	X	
16. Mexico	X			

17. Montenegro	X		
18. Myanmar		X	X
19. Nepal	X		
20. Netherlands			X X
21. New Zealand	X		
22. Nicaragua	X		
23. Nigeria		X	
24. Pakistan		X	
25. Peru	X		
26. Philippines	X		X
27. Poland			X
28. Sweden			X
29. Thailand			X
30. Timor-Leste	X		
31. UK	X		X
32. US	X		X
33. Vietnam		x	X

Secondly, for research question three, we conducted five deep-dive case-studies analysing the laws of five countries through the lens of a “community flood resilience” framework developed and implemented under the ZFRA and supplemented this with local expert discussions.

Community flood resilience framework has been developed for measuring and assessing flood resilience of communities across the world (Keating et al., 2017). In this framework, flood resilience is defined based on the five types of capitals i.e. financial (community’s and individual’s economic assets and financial supports), human (knowledge, awareness and skills of communities), natural (ecosystems and eco-services), physical (basic infrastructure and physical protection measures) and social capitals (social networks and people participation) (DFID, 1999, Keating et al., 2017, Campbell et al., 2019, Magnuszewski et al., 2019)—see figure 2. In this framework, the five capitals demonstrate the capacity for communities to avoid the creation of new risks, reduce existing risks, prepare for future risks and improve their response to and recovery from a flood event. Each of these capitals includes a set of indicators resulted into the 44 indicators of community flood resilience—shown in supplementary A. To our knowledge, this is the only framework developed for assessing “flood resilience” in the "community-level" and being used in various countries across the world. We use the indicators within this framework to investigate how and to what extend community level resilience is addressed in national laws of five cases studies.

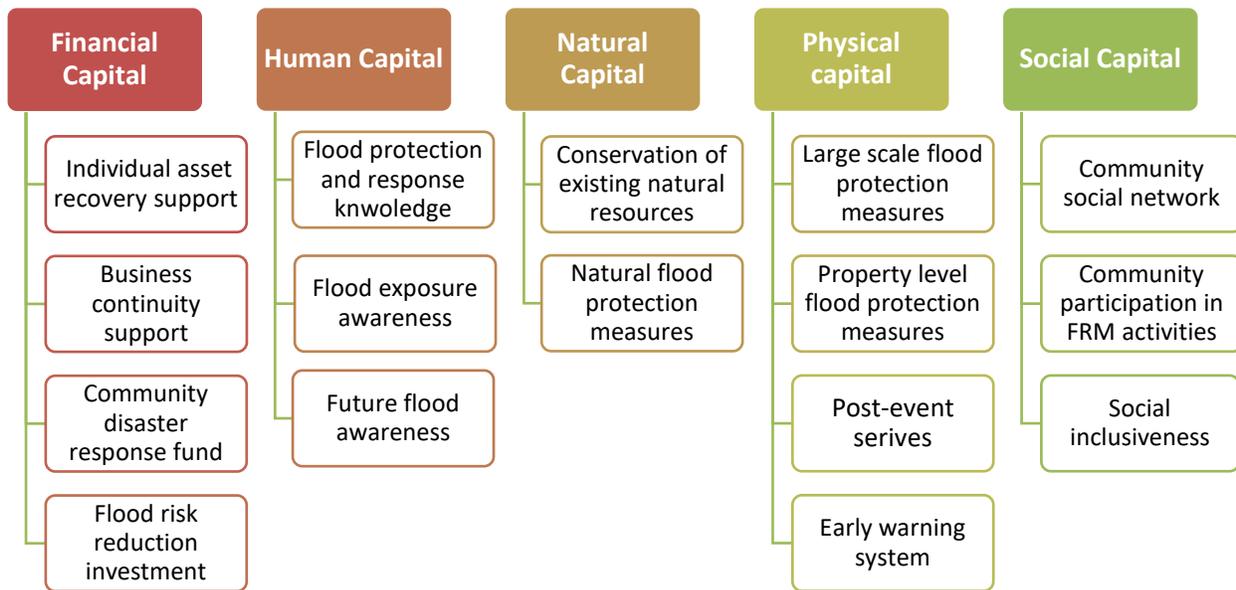


Figure 2: An overview of the FRMC framework and the simplified categories of indicators for each capital. For the complete list of 44 indicators see supplementary A.

Due to the exploratory nature of the research question three, the five case-study countries were chosen to cover a diverse range of economic and human development contexts (i.e. developed vs developing countries), political systems (i.e. federal states vs unitary states), government system (i.e. presidential, parliamentary, and constitutional monarchies), and different geographical locations (i.e. Asia, Europe, and America). These are Bangladesh (unitary parliamentary constitutional republic), Indonesia (unitary presidential constitutional republic), Nepal (federal parliamentary republic), United Kingdom (unitary parliamentary constitutional monarchy and FRM is devolved across regional administrations), and the United States (Federal presidential constitutional republic).

Here, we acknowledge that any study of this kind comes with some limitations:

Firstly, this study does not assert whether a country needs national laws, nor does it provide a ranking based on number of laws identified. Instead, we conduct a stock-take and investigate the role of existing laws in terms of current and future flood risk and resilience. We acknowledge that the use of legislation systems depends on political systems, general structure of government and governance culture of countries, and therefore, the lack of laws for an area such as flooding cannot automatically be interpreted as lack of flood governance—in Federal systems, for example, there is often very little or no national level legislation. Similarly, in some countries the executive route to decision making might dominate, with very little use of legislation in areas such as disaster, flood and climate change. Therefore a more comprehensive assessment of the countries’ regulatory responses to flood risks would need to take into account legislation as well as executive policies and strategies (Nachmany et al., 2019).

Secondly, the focus of this study is on primary laws⁷ but we acknowledge that those alone are certainly not the only foundations and determinants of flood-related decision making. Yet, primary laws play an important role in fostering collaboration, partnership and proper distribution of resources across governance scales and sectors, and geographical locations.

Finally, this study focuses on the laws that explicitly include flood, adaptation and/or natural disaster/hazard in their text (see supplementary A for the terms used for collecting laws). We do not consider the laws that may have an indirect impact on flood risk and resilience if they do not explicitly address flood, adaptation or natural disaster/hazard.

3. Results

Overall, across the 33 countries investigated we identified and analysed 139 laws (see supplementary C for the full list of the laws and analysis results) that exist in 30 countries (figure 3A). In Belgium, Nigeria and Egypt no national laws related to flood exist. Importantly, these three countries show flood-related policies and strategies across national and local levels, for example, Egypt's National Strategy for Adaptation to Climate Change and Disaster Risk Management (2011), and Nigeria's National Erosion and Flood Control Policy (2011) and National Policy on Climate Change and Response Strategy (2013) (Osumborogwu and Chibo, 2017). Belgium, in turn, is an example of a federal government system, where the responsibility for FRM sits with the three distinct regions of Brussels, Flanders and Wallonia and not with the federal government. This explains while there is no national law on flood or climate adaptation in Belgium, flood risk governance is organized through many regional policies, regulation, strategies and plans for flood and coastal risk management exist in these three regions (Castanheira et al., 2017).

3.1. Typology of national laws

This section will look at the typologies of laws in terms of their objectives and focus areas, the mechanisms used and the actors they target.

3.1.1. Objectives and focus areas

Analysing the 139 laws shows a variety of underpinning objectives aimed at different policy areas. The majority of laws' are either focused on water resource management (29%) or wider DRM (25%). The rest of the laws are focused on natural resource management (13%), climate change adaptation (9%) and land use and spatial planning (9%). Only 4% of laws are specifically focused on *flood* risk management strategies (figure 3a-3b). In terms of specific focus areas we find that:

- Water resource management laws are mainly about issues related to the water resource consumption, improving drainage systems and building watershed protection measures such as embankments and flood walls alongside the rivers e.g. water acts of Afghanistan (2009), Bangladesh (2013), China (1988), France (1992), Germany (2009), Honduras (2009), Indonesia (1974), Montenegro (2007), Poland (2001), and UK (2014).

⁷ Primary and secondary laws are created respectively by the legislative and executive branches of government. Primary law—also known as 'act'—generally consists of statutes that set out broad outlines and principles and delegate specific authority to make more specific laws following the principal laws. Secondary law—also known as 'regulation, delegated legislation or subordinate legislation'—is mainly issued as the result of the primary act and creates legally enforceable regulations and the procedures for implementing them.

- DRM laws cover the issues related to the protection, mitigation and reduction of the multi-hazard risks e.g. DRM acts of Bangladesh (2012), India (2005), Indonesia (2007), Myanmar (2013), and Pakistan (2010).
- Flood risk management laws are specifically about protection, prevention and control of flood risks such as the German 'Act to Improve Preventive Flood Control' (2005) and the US 'Flood Disaster Protection Act of 1973'.
- Natural resource management laws are about issues concerning conservation and preservation of the natural resources (non-water resources) that may protect communities against flood (such as natural parks and agricultural lands alongside the rivers) e.g. Albanian 'Law on Protected Areas' (2017), French 'Law for Reclaiming Biodiversity, Nature and Landscapes' (2016), and Nicaraguan 'General Law on the Environment and Natural Resources' (2014).
- Land-use and spatial planning laws are related to the issues on management, planning, and governance of land-uses, development projects and property/land rights e.g. 'Law about Spatial Planning' in Indonesia (2007) and 'The Building and Planning Act' of Sweden (2010).
- Climate change laws focus on strategies and actions for improving adaptation and mitigation mechanisms e.g. Climate Change Acts of Philippines (2009), Mexico (2012), New Zealand (2002), and Nicaragua (2009).

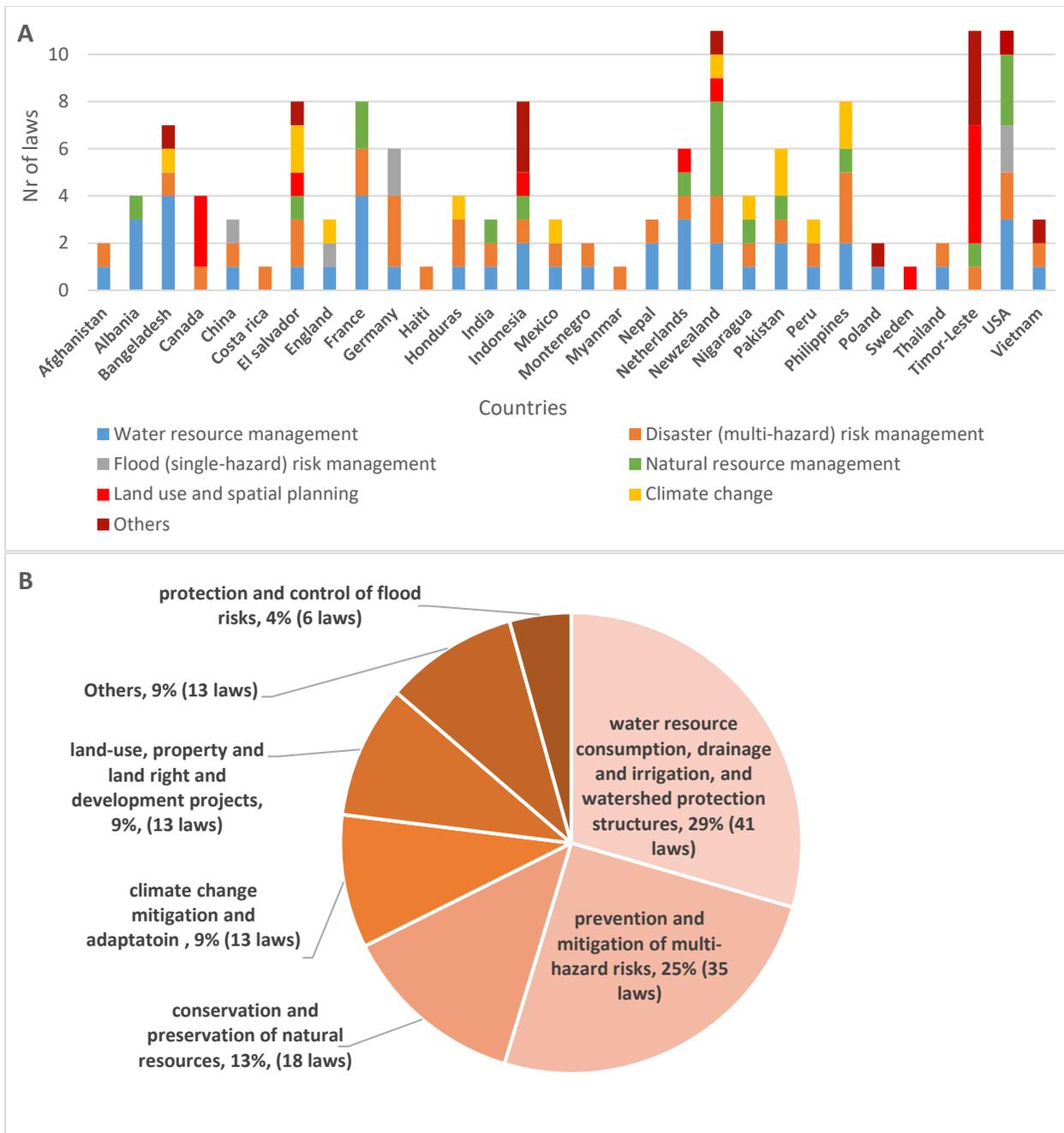


Figure 3: Overviews of the primary issue areas of the laws identified as relevant for flood risk management in 30 countries: A) per each country and B) total per each category across all countries. Numbers and percentages in 3B are the numbers and percentages of laws per each category.

A historical overview of the 139 laws identifies a shift in the policy areas of such laws. Figure 4 shows that before 1980, the rules and regulations for flooding were mainly outlined by the water resource and natural resource management laws. This can perhaps be explained by the argument that disaster risk governance, across the world, had been situated within the environmental and natural resource governance for a long time (Lemos and Agrawal, 2006, Tierney, 2012) following policies, regulations, decisions and actions that were tended to be based on *conservation, preservation and restoration* paradigm (Clarvis et al., 2014). In

such a paradigm, the ecosystems—and natural hazards—are assumed to be both predictable and therefore can be protected from the external drivers (Clarvis et al., 2014, Craig, 2010). Since the 1980s we see an emergence of laws related to DRM/DRR and adaptation as well as laws from other sectors such as spatial planning and finance, which seems to indicate a growing recognition of risk reduction and adaptation paradigms within FRM legislations.

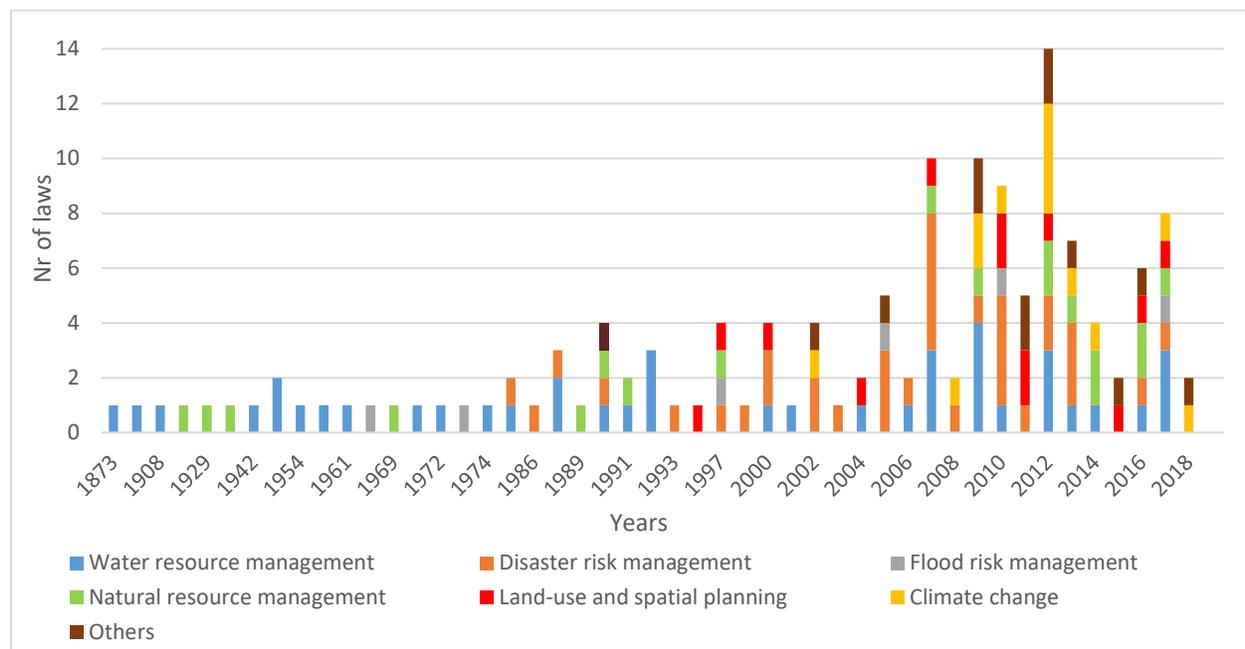


Figure 4: The publication year of 139 laws in 30 countries (1873 and 2018 are the years of the oldest and newest laws analysed). Belgium, Nigeria and Egypt do not have any law related to flood. Note that this figure shows the creation year of the laws and not their revision years.

3.1.2. Mechanisms used by laws

Across the laws analysed we can identify five different types of mechanisms through which the laws intent to influence the way floods are managed. In most of the cases, the laws encompass a combination of these mechanisms:

1. Setting up a new government body i.e. departments, committees, boards, councils, institutes, or associations that have FRM as part of their tasks, and establishing their functions, responsibilities and funding sources.
2. Establishing or clarifying roles, responsibilities and rights related to FRM activities. In addition to the previous mechanism that defines responsibilities as a part of the *new* organization, some laws merely focus on allocating mandates and responsibilities among the *existing* government and non-government bodies and actors.
3. Establishing or mandating the creation of a strategy, vision, policy, plan, regulation, assessment, criteria or guideline for FRM in the national, regional and local levels.
4. Mandating or regulating the implementation of specific projects, actions, or interventions, such as the construction, maintenance, management, and control of the flood defence and embankment.

5. Mandating or prohibiting funding, budget, fees or charges for FRM. This can be through the national flood insurance, local governments' funding, budget or compensation for risk reduction, response or recovery.

3.1.3. Who does the law target?

Overall, national-level public actors are given the dominant roles and responsibilities in all the laws analysed. Yet, the level of involvement of non-public actors (i.e. civil society, private sector and public-private partnerships) and local and regional governments varies in different countries' laws. Among the 30 countries, 16 countries define a sort of FRM ownership for the local government in addition to the regional/sub-national and national level government (e.g. UK, New Zealand, Pakistan and Philippines) and 7 countries engage communities (people, civil society and homeowners) in FRM activities. The latter is either through creation of community level governance structures/mechanisms (e.g. farmers' or water users' association) that can contribute in flood-related decision makings or by mandating involvement/participation of the civil society representatives in the process of FRM planning (e.g. 'National Disaster Management Act, 2010' of Pakistan and 'Law on the Integrated Management of Water Resources' in Albania), or through obliging implementation of property-level mitigation measures (e.g. 'Act on Managing Water Resources' in Germany). Besides, 10 countries identify the role of the private sector and 9 countries recognize the roles of the Non-Governmental Organizations (NGOs) in their national level laws, especially in light of strengthening cooperation and communication among the national/local governments and NGOs/private sectors for flood response and preparedness (e.g. 'Law on the national risk management system' in Honduras, 'Disaster Reduction and Management Act' in Philippines, and 'Robert T. Stafford Disaster Relief and Emergency Assistance Act' in USA). However, the laws of 11 countries (e.g. Netherlands, Mexico and India) solely rely on defining the roles and responsibilities of the national government and public sectors for FRM activities.

The role of multi-actor engagement is increasingly considered as a crucial element of flood risk governance (Alexander et al., 2016a, Wiering et al., 2018). For instance, in the Netherlands, the flood protection is a specific governmental competence by law, and therefore, government and public sectors have a dominant role in FRM responsibilities, which is reported as a driver of the limited contribution of other actors (Wiering et al., 2017). Whereas, in the UK, there are signs of the shift in the flood risk governance arrangements for England and Wales, which has been influenced by the Flood and Water Management Act. This act gives county and local authorities a local leadership role and the Environmental Agency a national overview role concerning FRM (Environment Agency, 2011, Alexander et al., 2016b), while a variety of sub-arrangements with specific roles for public-private and national-regional-local partners also exist (Wiering et al., 2017).

3.2. Temporal aspects of flood risk management in national laws

Flood events and risks are increasing over time due to the impacts of climate change (IPCC, 2018). This calls for 1) integrating climate change in future flood projections, and 2) focusing on reducing current and future flood risks through pro-active FRM—instead of reactive approaches that only focus on response and recovery after flood events. This section will look at how national laws address such temporal challenges of FRM.

3.2.1. Climate change and changing flood risks

Overall, there are a few examples of laws that mandate the inclusion of climate change in the projection, assessment and management of future flood risks, yet, most of the laws do not recognize the impacts of climate change in regulating decisions and actions for future flood risks. As seen in previous section, out of the 139 laws analysed, only 13 laws from 10 countries contain a specific climate change focus, out of which 7 laws have both adaptation and mitigation focus and 6 laws (from Bangladesh, El Salvador, Nicaragua, Pakistan and Philippines) merely look at adaptation. In total, 30 laws—21% of the total laws analysed—incorporate "climate change" in the document, most of which have been passed since 2002. Some of these laws emphasize on the inclusion of climate change parameter in the flood and hazard related policies and regulations to take account of dynamic future risks and resilience. For example, the 'Law Concerning Meteorology, Climatology and Geophysics' (2009) obliged Indonesian government to formulate climate change adaptation policies, strategies and programs, and monitor their applications which require monitoring climate change indicators and climatology data collection. The 'UK Flood and Water Management Act of 2010⁸ also mandates the specification of the current and predicted impact of climate change on flood risk in the national flood and coastal risk management strategy of the UK. Furthermore, our analysis shows that only 19% of the DRM laws analysed incorporate climate change in the document, demonstrating a significant lack of attention to climate-dependent changing risk in the mitigation and management of future disasters.

3.2.2. Pro-active vs reactive laws

National level laws can accelerate pro-active FRM by regulating the measures that assess and reduce the possible future flood risks. Flood risk reduction has been officially defined by the UN Office for Disaster Risk Reduction (UNDRR) as a systematic approach to identify, assess and reduce the risks of disasters (figure 5). A set of themes have been introduced in Hyogo and Sendai frameworks as well as IFRC reports that defines inclusion of risk reduction activities and strategies in legislative documents. Such themes include the provision of early warning system (EWS), provision of community education and public awareness, improving building codes, land use planning, land tenure and informal settlement, provision of risk-sharing and insurance, and improving public participation in DRR activities (IFRC and UNDP, 2014).

⁸ This act extends only to England and Wales, as Northern Ireland and Scotland have their own legislations.

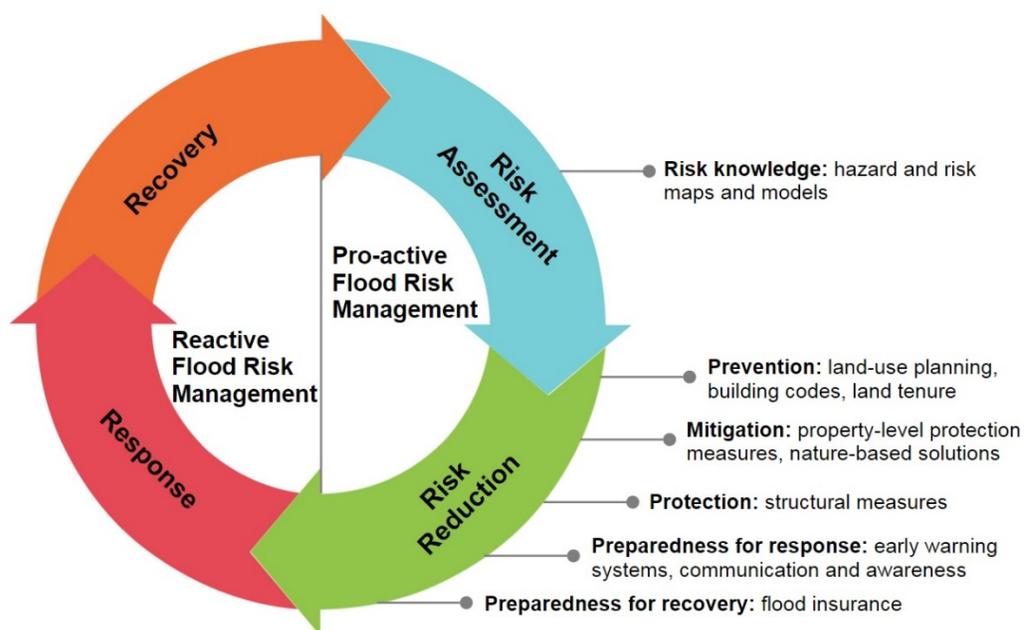


Figure 5: Proactive and reactive FRM. Adopted from (Surminski and Thieken, 2017) and (IFRC and UNDP, 2014).

35 out of the 139 laws analysed (from 26 out of 30 countries) have a DRM focus. This group of laws cover various aspects of DRM such as assessment, prevention, mitigation, protection, preparedness, response and recovery (figure 5). The earlier laws of this category are primarily focused on emergency management and preparedness and are often known as the “national calamity” or “emergency” laws e.g. the ‘Emergency Planning Act’ of 1986 in the US. Majority of the DRM laws have a holistic view on different aspects of DRM but do not include DRR elements as a priority in the law. These laws have been usually adopted in the 1990s and early 2000 and are not substantially updated in the last decade. Only 8 out of 40 DRM laws incorporated "DRR" in the document all of which have been passed since early 2002 and some tend to give a high priority to DRR compared to the other aspects of DRM e.g. DRM laws in New Zealand, Indonesia, Nepal and Philippines. However, some national laws may not use the terminology of "DRR" but have a strong focus on activities related to DRR such as EWS, risk mapping and funding risk reduction activities. In section 4.3 we analyse different aspects of DRR in national laws of five countries as a part of our resilience framework.

Figure 4 also shows the timing of laws in 30 countries analysed. The spike in the number of laws—starting from the beginning of 21 century—suggests a link to the increasing frequency and real impacts of flood events followed by the pressures from governments and international organizations for improving flood risk governance. Many of the flood-focused or DRM laws are made in the wake of significant disasters. In the UK, for example, the series of floods in summer 2007 triggered creation of the ‘UK Flood and Water Management Act’ in 2010, which was recommended by the Pitt Review; an independent review assigned by the British government for studying the drivers and impacts of the 2007 flood events (The Pitt Review Report, 2008). In the USA, the ‘National Flood Insurance Act of 1968’ was promoted as a result of the destruction caused by flood surges from Hurricane Betsy in Florida and Louisiana in 1965. In France, following the serious flooding of 1981, the French parliament voted a law issued in 1982 to institute a new compensation system for natural hazards (Magnan, 1995). In Germany, the hundred-year flood of

summer 2002 provided the background to the German federal parliament passing the 'Flood Control Act' in 2005 to introduce nationally binding requirements for the prevention of flood damage (Kienzler et al., 2015, Thielen et al., 2016). In Indonesia, the tsunami of September 2004 that caused tremendous loss of life and destroyed large numbers of properties and infrastructure in the province of Aceh led to the development of the comprehensive 'Law Concerning DRM' in 2007 (IFRC and PMI, 2014). These and many similar examples indicate that law-making for flood and disaster risk has often been a post-event response by governments rather than a proactive intervention for flood risk reduction (see supplementary B for a comparison between the history of flood events and flood-related laws created in the 33 countries). This also distinguishes the difference between the DRM laws and adaptation laws, the latter of which provide forward-looking consideration of the future flood risks.

3.3. Role of national laws in community flood resilience

This section explores framing and focus of the national laws in the context of flood resilience. 16 out of 139 laws (from 12 out of 33 countries) incorporate the word 'resilience' and three laws, from Mexico, Peru and the Philippines, provide a clear definition of 'resilience' in the laws. These three laws follow the UNDRR's definition of resilience: "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNDRR, 2016). In most of the cases, resilience has been used in relation to climate change adaptation; The Mexican 'General Law on Climate Change' (2012) determines "strengthening the resilience of natural and human systems" as one of the main objectives and criteria in formulation and evaluation of the Mexican national policy on climate change adaptation. The 'Philippine Disaster Reduction and Management Act' (2010) emphasis on strengthening the capacity of the national government in building community resilience to climate change impacts. 'Climate Change Act' of Philippines (2009) applies resilience in the context of addressing the Hyogo Framework for Action i.e. building *community resilience to climate change-related disasters*. Mexico and Pakistan laws on climate change incorporate resilience to climate change adaptation and promoting climate-resilient development.

However, using the term of "resilience" per se is not the only way of incorporating resilience thinking in legislative documents. National legislations can enhance community resilience in many ways and through various functions and instruments. In this section, we presents the result of our deep analysis on the laws of five case study countries i.e. Bangladesh, Indonesia, Nepal, UK, and the USA, using the indicators from community flood resilience framework presented in the figure 2 (Keating et al., 2017).

Table 2: The five case studies and the laws studied for each country

Country	Flood related laws
Bangladesh	<ol style="list-style-type: none"> 1. Embankment and Drainage Act, 1952 2. River Research Institute Act, 1990 3. The Bangladesh Water Development Board Act, 2000 4. The Climate Change Trust Fund Act, 2010 5. Disaster Management Act, 2012 6. Bangladesh Water Act, 2013 7. Wealth Act, 2018
Indonesia	<ol style="list-style-type: none"> 1. Law 11/1974 on Water Resources Development, 1974 2. Law No. 24/2007 Concerning Disaster Management, 2007 3. Law Number 26 of 2007 About Spatial Planning, 2007 4. Law 31/2009 Concerning Meteorology, Climatology and Geophysics, 2009 5. Law Number 18 of 2012 About Food, 2012 6. Law Number 19 of 2013 About Protection and Empowerment of Farmers, 2013 7. Law No. 7 of 2016 Protection and Empowerment of Fishermen, Fish Cultivators and Salt Farmers, 2016 8. Law Number 7 of 2004 About Water Resources, 2004
Nepal	<ol style="list-style-type: none"> 1. Soil and Watershed Conservation Act, 1982 2. Water Resources Act, 1992 3. Disaster Risk and Management Act, 2017
The United Kingdom	<ol style="list-style-type: none"> 1. UK Flood and Water Management Act, 2010 2. Water Act, 2014 3. Climate change act, 2008
The United States	<ol style="list-style-type: none"> 1. Watershed Protection and Flood Prevention Act, 1954 2. National Flood Insurance Act of, 1968 3. National Environmental Policy Act, 1969 4. Clean Water Act, 1977 5. Flood Disaster Protection Act, 1973 6. Emergency Planning & Community Right-to-Know Act, 1986 7. Robert T. Stafford Disaster Relief and Emergency Assistance Act, 1988 8. North American Wetlands Conservation Act, 1989 9. Coastal Wetlands Planning, Protection & Restoration Act, 1990 10. Global Change Research Act, 1990 11. Water Infrastructure Improvements for the Nation Act, 2016

3.3.1. Financial Capital

National legislations may support financial capital by regulating, suggesting or encouraging the creation and distribution of any economic resources that support communities against floods, e.g., insurance, loans, grants, funds and compensations.

Among the five countries, **USA's** and **UK's** national laws support the *individual's asset recovery* and *business continuity* (figure 2) through creating or improving an affordable national insurance. 'Water Act 2014' in the UK establishes a public-private flood reinsurance scheme (i.e. FloodRe) to promote availability and affordability of flood insurance for the households while minimising the cost of doing so for the insurance companies. The USA 'National Flood Insurance Act of 1968' creates a government-provided flood insurance program and establishes criteria for premium reductions given flood protection and risk reduction projects. Later amendments of this act made the purchase of flood insurance mandatory for

properties within floodplains and allowed the rise of premiums in high-flood areas to reflect the real risk of living in such areas and ceased subsidizing flood insurance for properties that had been flooded multiple times.

National laws' contribution to the provision of *community disaster fund* depends on the political and governance situation of countries. For example, the national law of the **USA** authorizes the president to make loans to *local governments* which may suffer a substantial loss of revenues as a result of the flood. As such, the communities have access to some flood emergency and recovery funds, yet activation of these funds require decisions made outside the communities—at the federal or state level. For example, in the flood 2008 in Linn Iowa (one of the ZFRA project's studies) funds were obtained from the Federal Emergency Management Agency (FEMA) because it was a federally declared disaster, whereas in the flood 2016 the Linn country got a state-level declaration which only provided grant for the public sector. **Indonesian** 'Law Concerning DRM', in contrary, mandates the national and regional governments to create the community disaster response fund—known as disaster aid—that is available for *individual members* of the community in the form of compensation money for disability, soft loan for business recovery, or aid for necessities. The ZFRA surveys and interviews in Indonesia shows that in 36 out of 40 communities analysed, the local flood emergency and recovery fund exists for the community members. However, 61% of the total community members either were not aware of the existing funds or claimed that they did not have access to such funding during the previous floods. This presumably indicates that regulating the creation of flood emergency funds without a mechanism for fair distribution and communication of such funds does not support the financial recovery of the communities.

We did not identify any law at the national level in the five countries that mandate budgets for *DRR investment*, although some countries bundled risk reduction into their national DRM funding. For example, the 'Stafford Act' of the **USA** obligates the creation of federal funding programmes for disaster resilience and mitigation for local government, which comes from the general budget of the Federal Emergency Management Agency.

3.3.2. Human Capital

National laws may contribute in increasing the community's *knowledge on flood response and preparation* by creating relevant governance structures, responsibilities and funding. The **USA** act on 'Water Infrastructure Improvement' mandates all the non-federal sponsors of dam rehabilitation projects to demonstrate a Floodplain Management Plan. Increasing *public education* and *awareness of flood risk* in areas that are protected by the dam project is among the measures that should be included in this plan. The 'Stafford Act' of the **USA** also obligates administer of the federal emergency management agency to provide funds for the education and training in life-supporting *first aid* to children. In **Indonesia**, 'Law Concerning DRM' provides right for all flood-prone community members to receive education, training, and skills in disaster management, participate in planning for physical and psychological healthcare aid and obtain information on disaster management policies. Moreover, this law obligates all member of communities to provide correct information to the public on disaster management. Yet, it does not provide specific national-level regulation on how to do these. The ZFRA surveys and interviews show that the majority of the community members (above 75%) in Indonesia—as well as the other five countries—has not received any first aid training.

Raising awareness about the current flood risk exposure has been mainly encouraged in countries' laws via creating or improving flood zone maps and models. All five countries analysed have at least one law

that mandates the creation of flood zone maps or identification of high flood risk zones. However, such maps are often meant to be used for providing information for governments and DRM bodies rather than raising flood awareness among the communities. The '**Bangladesh** Water Act' (2013) gives power to the executive committee of the water resources council to declare any wetland as a flood control zone based on the inquiry and survey results. The **Indonesia** 'Law Concerning DRM' also provides the task of preparing, deciding on, and disseminating the maps of disaster-prone areas for the Local Agencies on DRM. After disseminating the maps to the government bodies, it becomes the responsibility of the Indonesian government to revoke or reduce the proprietary rights in such areas and provide compensation for the property holders under the legislation. The ZFRA reviews and surveys indicate that most of the communities in Nepal, Bangladesh, Indonesia and the US have a roughly accurate perception of the flood exposure but according to the local knowledge such awareness has been triggered by the previous flood events and not by the flood zone maps and models.

To raise *awareness about the future flood risk*, some laws encourage research on the impact of climate change on natural hazards and dissemination of climate change information for the public. **Bangladesh** 'DRM Act' regulates establishment of National Disaster Management Research and Training Institute to research on the effects of climate change and future risk and assesses the capability of disaster management methods considering the future flood risk predictions. The **Indonesia** 'Law Concerning Meteorology, Climatology and Geophysics' obliges Indonesian government to enhance awareness and participation of people in climate change adaptation activities through fostering data collection, analysis and monitoring of climate change and dissemination of information with the public.

3.3.3. Natural Capital

Protection, conservation and preservation of existing natural resources such as water resources, farmlands, green lands, floodplains, wetlands and other ecosystems are often addressed in the laws related to water resource management and environmental management. Among the laws of the five countries, 'Clean Water Act' of 1977, 'National Environmental Policy Act' of 1970 and the 'North American Wetlands Conservation Act' of 1989 in the **USA**, the 'Soil and Watershed Conservation Act' in **Nepal**, 'Law Concerning DRM' in **Indonesia**, and 'River Research Institute Act' in **Bangladesh** all emphasise on regulating policies, studies, plans, and creating responsibilities for protecting the existing natural resources. However, no law encourages or regulate the application of *new natural protection measures* or *nature-based adaptive solutions* for flood risk reduction and protection, despite the increasing importance of such measures in recent FRM's discussions (Hartmann et al., 2019, Jongman, 2018, Schanze, 2017).

3.3.4. Physical Capital

Implementation of the *large-scale flood protection* projects, also known as structural measures, are mainly regulated or encouraged in the water resource management laws of the five countries by creating policies, responsibilities, and funding for these projects, e.g., 'Embankment and Drainage Act', 'Water Development Board Act' and 'Water Act' in **Bangladesh**, 'Soil and Watershed Conservation Act' in **Nepal**, 'Watershed Protection and Flood Prevention Act' of the **USA**. Yet, we did not find any laws that support or regulate *property level flood protection measures*, which are probably considered in local plans and regulations of these five countries.

Improvement of *post-event services* are considered in the DRM laws that identify departments and responsibilities for disaster response, relief, rehabilitation and reconstruction. DRM Acts of **Indonesia** and **Bangladesh** identify fulfilment of necessities (i.e. water, food, healthcare, accommodation and clothing) as one of the main components of emergency response and shares its responsibility among the national, regional and local disaster management bodies.

Creation and use of *EWSs* have been proposed and encouraged by national laws of many countries as a method to increase the public awareness and preparation for future floods. Some laws only emphasise on the creation of EWS as the main requirement of DRM e.g. 'UK Flood and Water Management Act', while others specify details and directives for the implementation of EWSs. **Bangladesh** 'Weather Act 2018' creates the Bangladesh Meteorological Department and regulates the establishment of a weather forecasting centre that creates weather alerts and warnings. 'Law Concerning DRM' in **Indonesia** identifies EWS as a set of actions from observation and analysis of disaster signs to decision-making by authorities, dissemination of information and community actions, and regulates related roles and responsibilities. 'Stafford Act' of the **USA** mandates modernization of EWSs and integration of national and local EWSs.

3.3.5. Social Capital

National flood laws may contribute in improving the *communities' social networks* by demanding the creation of local flood response and recovery plans that coordinate individuals' activities or via suggestions for improvement of social safety in the flood-prone communities. National flood laws can also regulate or encourage *people participation in FRM activities* e.g. in the process of preparing policies, plans, and strategies for FRM, or designing and implementing flood risk reduction interventions.

Bangladesh 'Disaster Management Act' obligates the creation of local disaster management plan based on each area's specifications and local hazards. The 'UK Flood and Water Management Act' of 2010 mandates creation, maintenance and application of a strategy for local FRM by lead local flood authorities who must consult the public and local risk management authorities about these strategies.

The **Indonesia's** 'Law Concerning DRM' identifies right for all members of communities to participate in decision-making on DRM activities. This law encourages participatory disaster management planning particularly for DRR and reconstruction activities. Also, it obligates governments to increase communities' participation in the provision of funds and aids. However, the ZFRA interviews and surveys in Bangladesh and Indonesia shows that in majority of communities analysed (32 out of 40 in Indonesia and 6 out of 9 in Bangladesh) there is no local flood plan available and in 5 communities in Indonesia and 3 communities in Bangladesh the flood plans have not been developed in a participatory way and have not been communicated within the communities.

In term of the *Inclusiveness*, the **Indonesia's** 'Law Concerning DRM' emphasis on providing the equal right for all community members to receive aid for basic needs and compensation for losses from disaster besides benefiting from social security in flood-prone areas. The **Bangladesh** 'Disaster Management Act' obliges the government to give preference to the protection and risk reduction for vulnerable communities affected by flood events including minorities, older persons, women, children and handicapped persons. 'Stafford Act' of the **USA** also requires the EWSs to provide information to individuals with disabilities, special needs and limited English proficiency.

4. Discussion and conclusion

Flood risk governance is structured differently across countries and regions and has often evolved over time, driven by cultural and historical aspects as well as the scale and real impact of flood risk experienced. This study provides insights on understanding the role that national laws can play in enhancing flood resilience and adaptation.

Our analysis of 139 laws in 33 countries shows that, historically, there has been a shift in flood laws away from an initial focus on flooding as a natural resource and water resource management issue towards a broader set of laws that consider flooding within disaster risk management and climate adaptation policy. Indeed, climate change adaptation appears as a new paradigm for legislation aimed at managing flooding, usually mentioned up-front in the justification of flood laws. However, we find a significant lack of detailed climate change recognition within flood related laws. This is underpinned by our observation of a disconnection between flood/disaster-specific laws and climate change laws: both are often separated and largely working in isolation in most of the countries, as highlighted in the results. This underlines the importance of enhanced integration of flood risk management and climate adaptation (IFRC, 2019). Continued separation of ‘adaptation’ and ‘flood risk management’ laws can lead to gaps in institutional ownership and responsibility, and to separate budgets. This could also mean that investments in flood prevention might be based on current risk levels and underestimate future risk trends, reducing their effectiveness.

Moreover, the historical analysis of the 139 laws indicate that creation of the new DRM legislations has often been a post-event response to the major flooding. The content analysis of the DRM laws across countries demonstrates that flood risk reduction and prevention (known as proactive FRM strategies) are not prioritized in such laws and, still, a larger focus is on response and recovery (known as reactive FRM strategies). However, the predicted impact of climate change (i.e. dramatic increase of temperature, precipitation and sea level) calls for the ex-ante, pre-event and proactive policymaking and governance which needs to be considered in the legislation making of countries too. A shift to anticipatory action is difficult for many reasons (Surminski et al., 2016), and laws could play an important role in facilitating this adjustment, for example by requiring any flood risk assessments to consider current and future risks and resilience levels, or by setting out how climate change trends need to be taken into account when making infrastructure or land-use decisions. This is particularly important in the context of so-called slow-onset changes, such as sea-level rise and coastal erosion, which do require difficult decisions about pre-emptive resettlement or managed retreat which are likely to be politically difficult and unpopular.

The deep-dive analysis of the role of national laws in supporting community flood resilience shows that there is very little recognition of natural capital as a key component of increasing flood resilience. The national laws investigated are predominantly focused on physical and human capital, for example early warning systems, flood zone maps and models, and building large scale flood protection measures. However, the analysis did not identify any national law that explicitly promotes creation of the new natural protection measures (i.e. nature-based solutions) as a FRM and climate adaptation strategy. This is an area that will require further attention as natural flood risk management efforts do offer many advantages over ‘hard’ engineered measures such as seawalls, including environmental benefits. However, natural capital often remains unrecognized or underfunded. This underlines the importance of treating FRM and adaptation as a broad and holistic concept: ensuring the necessary human, social, physical, natural and financial systems are in place to address climate impacts when they occur. Climate

change cuts across all of these systems, which in turn are complex and interrelated, and trying to tackle adaptation or FRM focusing on only one system is likely to fail (Surminski and Szoenyi, 2019).

A final point warranting further attention is the question whether or how the laws are being implemented within countries. Case studies from the Zurich Flood Resilience Alliance (as describe in section 3.3) highlight that despite existence of comprehensive laws for FRM (particularly in the cases of Indonesia and Bangladesh), those laws have rarely been implemented properly and equally across those countries. Therefore, further investigations into the implementation and the impact of these laws would be important.

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Supplementary A

1. Method and Methodology for analysing questions 1 and 2: Typology, target and temporal aspects of national laws

Method: Desk study and content analysis of 126 laws plus reviewing the reports and literatures of “Disaster Law Database”.

Methodology for collecting and analysing relevant documents

Sources used:

- Climate Change Laws of the World, Grantham Research Institute, LSE, UK (<http://www.lse.ac.uk/GranthamInstitute/climate-change-laws-of-the-world/>)
- IFRC Disaster Law Database (<https://www.ifrc.org/en/publications-and-reports/idrl-database/>)
- Data sense-checking with other sources:
 - Ecolex: the gateway to environmental law (<https://www.ecolex.org/>)
 - PreventionWeb (<https://www.preventionweb.net/english/>)
 - NDCs
 - National legislature website of countries
 - National department, agency, ministry websites
 - Google
 - ZFRA alliance partners and local experts involved

Keywords used in identifying relevant laws to flood:

- Climate (change) adaptation
- Flood
- Different types of flooding
 - Fluvial/river flood
 - pluvial/surface water flood
 - coastal flood
 - flash flood
 - inundation
- Other disasters that may cause flooding
 - Tsunami
 - Storm
 - extreme weather
 - Changes in average precipitation
 - tidal waves
 - hurricanes
 - surface water change
 - atypical/extreme rainfall
 - sea level rise/change
- Disaster
- Adapt

Process for collecting laws:

1. Search key-words in databases and collect laws if they are (1) climate change adaptation-explicit, (2) flooding-explicit, or (3) DRM-explicit¹. Do not collect sub-national legislation or laws/policies that otherwise are outside the scope of the database (i.e. NAPAs, treaties/declarations, resolutions ratifying international conventions, rules from memoranda, and procedural regulations).
2. Determine if laws are still valid (i.e. not repealed/rescinded/overruled). Add notes where needed.
3. Make note of possible items (for further review) that technically do not match the eligibility criteria but may, as exceptions, deserve inclusion.

Texts were included in the dataset if they met the following criteria:

1. They were produced by a country’s central legislature.
2. They contained at least one substantive provision relating to climate change adaptation, disaster risk, or floods.
3. They were currently valid.

Framework for analysing laws

Categories	Definition
Function/ Instrument	What does the law/policy actually do? What are the aims and objectives of the laws?
Actors	Who is governing this law? Oversight = who is responsible for overseeing the functions of this law/policy? Delegated = who does this law/policy delegate responsibility to? Implicated = who does this law/policy say is important for achieving the law/policy's goals but is not directly responsible for governing them? Funding = who does this law make/policy responsible for providing funding? Creates = this institution/organization/body is created by this law/policy
Key words: Incorporation of climate change, resilience, and risk reduction	Do these terms appear in the law/policy? Resilience (e.g. does the policy/plan/law specifically reference ‘resilience’ as a concept), Disaster Risk Management/Reduction/Prevention/Mitigation/Control/Response/Recovery - term referenced, Disaster Risk Reduction – term referenced, Sendai framework – term referenced, SDG – term referenced, Hyogo – term referenced, UNFCCC/Paris Agreement – term referenced, Climate Change – term referenced, Adaptation – term referenced.
Policy Area	Which policy area does the law aims to cover/influence? Can be found in the aims and objectives of the law or the first page of the law description + title of the law – May need further content analysis if it is not mentioned in the title/first page/aims and objectives

Such analysis was checked and complimented with the countries legislative report and literature studies.

¹ Meaning Climate Change adaptation/flooding/DRM has been explicitly mentioned and discussed in the content of laws.

2. Method and Methodology for analysing questions 3: community flood resilience in national laws

Method: Desk study and content analysis of laws in five countries (i.e. Bangladesh, Nepal, Indonesia, US and UK) plus analysing qualitative data collected from key focus discussions and households' surveys in these countries via ZFRA project.

Framework for content analysis of laws:

We have analysed the law using the Flood Resilience Measurement for Communities (FRMC) framework developed by Zurich Flood Resilience Alliance (ZFRA)². In this framework community resilience is defined based on the five capitals of the Sustainable Livelihood Framework:

- *Financial capital* is any financial resources that support communities against flood. This can be either individual (household's or business's) savings, credits, or insurance supports that can be used for recovering from flood damage or the government grants and funding that individuals or communities can apply for and use for disaster response or flood risk reduction activities.
- *Human capital* is about the knowledge, awareness and skills of the community members. This source of resilience assess individual's (1) knowledge and skill about what actions to take before and during a flood event, in order to prevent death, injury and damage, and (2) awareness about their exposure to the current and future flood risk.
- *Natural capital* is about the natural resources that derive livelihood of communities and work as a flood risk prevention measure, or support communities to cope with or recover from the impacts of flood events. This source of resilience assesses how 1) the existing natural resource are maintained and preserved or 2) new natural measures are built in order to reduce the flood risks.
- *Physical capital* is physical items such as buildings, assets and infrastructure that support livelihood. This source of resilience assesses the measures protecting physical capitals before the flood (via either large scale projects, e.g. dams, walls, etc., or property level flood protection measures), after flood (via improving post-event access to health, clean water, food, energy, and proper infrastructures), or early warning system.
- *Social capital* is about the social relationships and institutions (i.e. formal and informal norms, rules and policies). This source of resilience assesses the social capacity of communities to reduce impact of flood risks before and after the flood events through the 1) social network within the communities, 2) participation of communities in flood risk management activities, and 3) social inclusiveness.

For each capital a set of indicators are defined shown in table 1 together with the questions and keywords that we used to identify each indicator inside texts.

² Up to now, this framework and its associated tool have been used for measuring flood resilience and supporting decision making in 9 countries and 118 communities across the world ([Campbell et al., 2019](#)).

Table 1: list of the resilience indicators and related questions and keywords for the law analysis

	Sources of resilience	Questions	Keywords
Financial	Household asset recovery	Does the law regulate or propose any funding or financial support (e.g. government grant or affordable insurance) for communities to repair or replace property/asset damaged or lost due to flood?	Budget, fund, grant, financial support, tax, levy, subsidy, charge, insurance, compensation
	Community disaster fund	Does the law regulate or propose any fund, budget or grant that a household, community member or local authority can individually apply for?	
	Business continuity	Does the law regulate or propose a fund, budget or grant that businesses can apply for?	
	Household income continuity strategy		
	Risk reduction investments	Does the law regulate or propose a dedicated budget/fund/grant for communities (e.g. local authorities) for improving or building structures that protect against flood risk?	
	Disaster response budget	Does the law regulate or propose a dedicated budget/fund/grant for flood/disaster response?	
	Conservation budget	Does the flood-related law regulate or propose any budget or grant for natural/ecosystem protection/conservation that communities can apply for?	
Human	Evacuation and safety knowledge	Does the law regulate or propose creation of a community flood safety and evacuation plan?	Knowledge, awareness, education, information, zone, map, model, exposure, climate change, uncertainty
	First aid knowledge	Does the law regulate or propose (any organization, plan, budget, responsibilities, etc.) for raising first aid knowledge and awareness among communities?	
	Education commitment during floods		
	Flood exposure awareness	Does the law regulate or propose creation of facilities/structures/organizations/responsibilities/etc. to inform communities of flood zones (flood zone map, model, etc.)?	
	Asset protection knowledge	Does the law regulate or propose providing knowledge for communities about the measures they can take to protect their assets from flood (before flood happens)?	
	Future flood risk awareness	Does the law regulate or propose consideration of future flood risk (including impact of climate change) in the FRM documents and in the process of risk communications with communities?	
	Water and sanitation awareness	Does the flood related law regulate or propose improvement of water and sanitation awareness among communities for post flood events?	
	Environmental management awareness		
	Governance awareness		

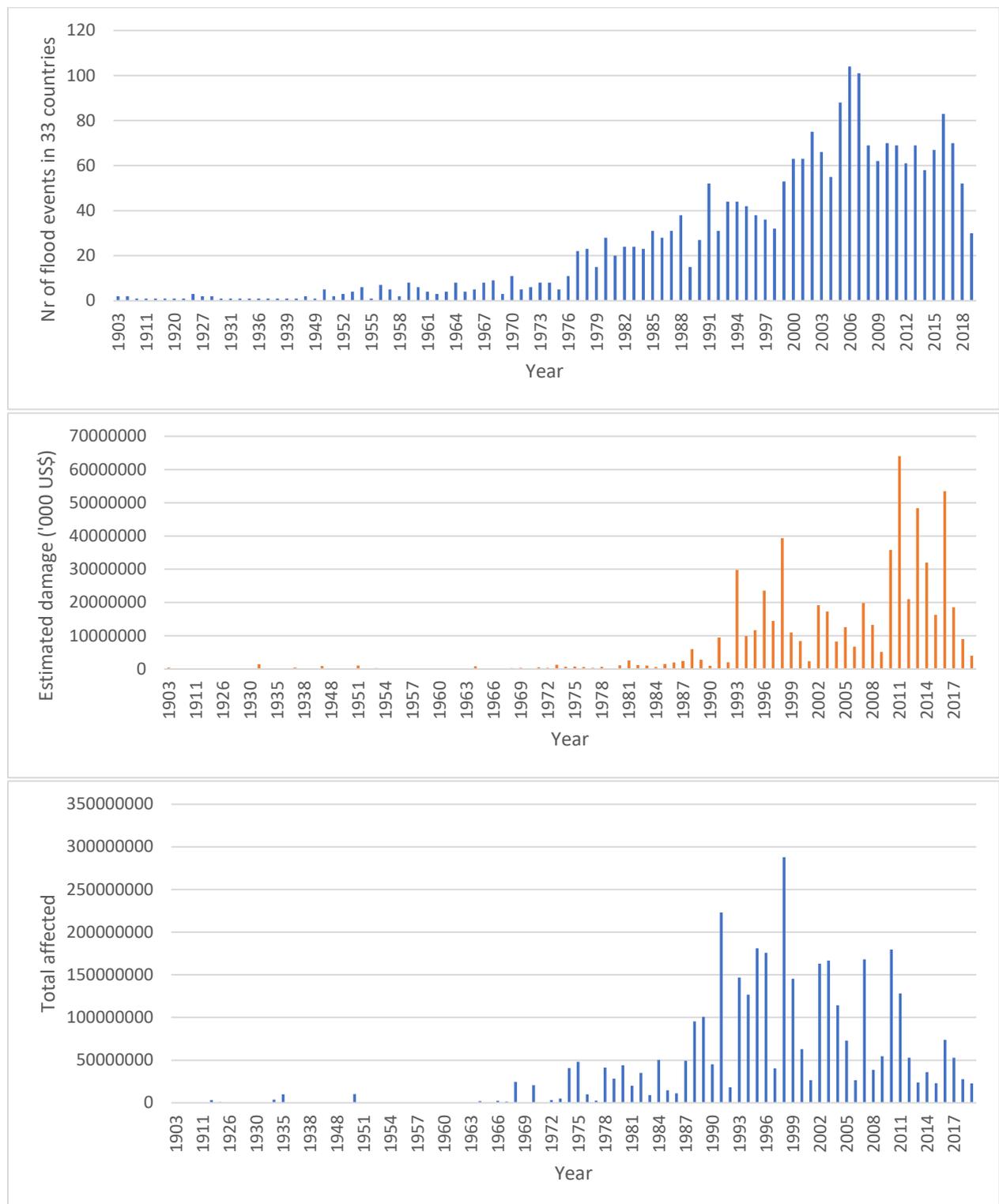
Natural	Natural capital condition	<p>1. Does the flood-related law regulate or propose any plan/ responsibility/policy/actions/etc. for protection/conservation of natural/ecosystem environment? OR</p> <p>2. Does the law regulate or propose any natural flood protection measure?</p>	<p>natural, priority, conservation, habitat, restoration, environment, ecosystem</p>
	Priority natural units		
	Priority managed units		
	Natural resource conservation		
	Natural habitat restoration		
Physical	Flood healthcare access	Does the flood-related law regulate or propose improving healthcare access for people particularly when flooding occurs?	<p>project, measure, intervention, action, structural, physical, protection, investment, warning, alarm, emergency, transportation, communication, food, water, waste, energy, health, embankment, dyke, dam, flood wall, drainage, contamination</p>
	Early Warning Systems (EWS)	Does the law regulate or propose creation of early warning system/ alarm/ light/etc. for communities?	
	Flood emergency infrastructure	Does the law regulate or propose creation of flood emergency infrastructure for the communities?	
	Provision of education		
	Household flood protection	<p>Does the law regulate or propose any funding, responsibilities, or creation of organizations or mechanisms that support, encourage, or facilitate “property level protection”/ “large scale flood protection” measures? Does the law regulate or propose improving the “transportation situation”/ “Communication interruption”/ “Flood emergency food supply”/ “Flood safe water”/ “Flood waste contamination”/ “Flood energy supply” when flood occurs?</p>	
	Large scale flood protection		
	Transportation interruption		
	Communication interruption		
	Flood emergency food supply		
	Flood safe water		
	Flood waste contamination		
Flood energy supply			
Community participation in flood related activities	Does the law regulate or encourage people participation in preparing policies, plans, strategies, etc. or other flood risk management activities?		<p>Communication, participation, safety, plan, coordination, interaction, people/community/civil society/ participation, local, household, property owner</p>
External flood response and recovery services	Does the law regulate creation of any flood response and recovery plan within the communities?		
Community safety	Does the flood-related law regulate or propose improvement of community safety?		
Community disaster risk management planning	Does the law regulate or propose creation of any community flood/disaster risk management plan?		
Community structures for mutual assistance	Does the law regulate or propose creation of a community level/ local flood coordination organization/structure?		

Community representative bodies		
Social inclusiveness	Does the law regulate or propose social inclusiveness (including all vulnerable groups) in community flood decision making and flood preparedness/response/recovery plans?	
Local leadership		
Inter-community flood coordination		
Integrated flood management planning	Does the law encourage coordination, cooperation and collaboration between community and other actors (e.g. government, business, civil society, etc) in creation of a flood management plan?	
National forecasting policy & plan	Does the law regulate or propose (responsibility of creation of) any national forecasting policy and plan and promotion?	

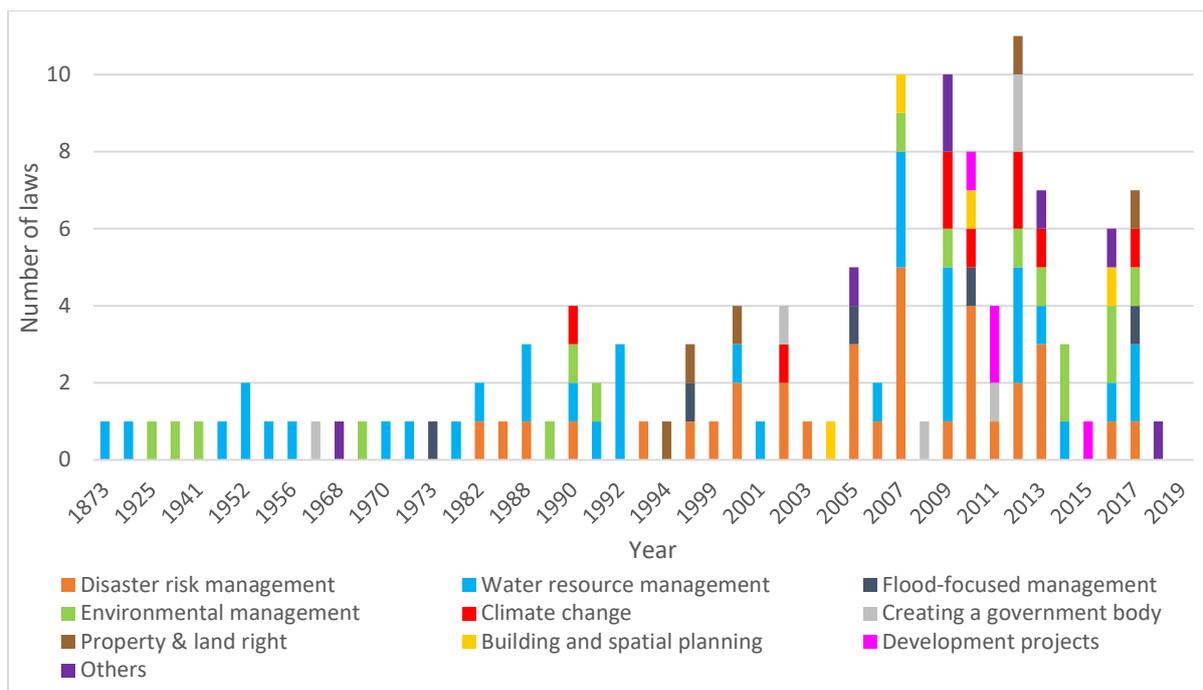
In addition, we used the insights from the key informant interviews and households’ surveys (via ZFRA projects in these countries) plus the country report and studies to complement our data analysis. An overview of the ZFRA project and case studies can be seen in <https://floodresilience.net/frmc>.

Supplementary B

Historical comparison between number of floods, total damages of floods, total affected of floods and number of flood-related laws in 33 countries.



Source: https://www.emdat.be/emdat_db/ last access: August 2019



Glossary of dataset

Estimated damage: The amount of damage to property, crops, and livestock. In EM-DAT estimated damage are given in US\$ ('000). For each disaster, the registered figure corresponds to the damage value at the time of the event, i.e. the figures are shown true to the year of the event.

Total affected: In EM-DAT, it is the sum of the injured, affected and left homeless after a disaster.