Institut für Lebensmittel - und Ressourcenökonomik

Assessing the potential role of insurance in flood adaptation in the context of climate change

a case study of the West African Lower Mono River Basin (LMRB) in Togo and Benin

Inaugural-Dissertation

zur

Erlangung des Grades

Doktor der Agrarwissenschaften

(Dr. agr.)

der

Landwirtschaftlichen Fakultät

der

Rheinischen Friedrich-Wilhelms-Universität Bonn

von

Simon Matthias Wagner

aus

Passau, Deutschland

Bonn 2024

Referent: Prof. Dr. Jakob Rhyner

Korreferentin: Prof. Dr. Swenja Surminski

Tag der mündlichen Prüfung: 13.05.2024

Angefertigt mit Genehmigung der Landwirtschaftlichen Fakultät der Universität Bonn

Acknowledgements

I would like to express my deepest gratitude to several persons and institutions whose support enabled me to conduct this dissertation project in a successful manner. First of all, I would like to thank the United Nations University - Institute for Environment and Human Security (UNU-EHS), the Munich Climate Insurance Initiative (MCII) for granting me the opportunity to conduct this research within the scope of the CLIMAFRI project. Simultaneously, I would like the Federal Ministry of Education and Research (BMBF) for funding the research project. On the same note, I want to thank my academic supervisor Prof. Dr. Jakob Rhyner for his attentive and supportive guidance as well as for always sharing intelligent and constructive feedback. I would like to thank Dr. Yvonne Walz, especially for her support in planning and carrying out the research activities and steering the CLIMAFRI project through uncertain and unprecendented times shaped by the global implications of the COVID-19 pandemic. Moreover, I would like to thank the MCII coordinator Michael Zissener for his constant and genuine support while undergoing my process as a Ph.D. Researcher. In addition, I would like to thank Sönke Kreft and Dr. Maxime Souvignet for their advice and feedback particularly during the initial stages of the research project.

The continuous feedback and guidance of colleagues helped to refine the direction of the project. Aside the wonderful colleagues from MCII, UNU-EHS and from the CLIMAFRI project, I would like to highlight several people. First of all, Dr. Sophie Thiam and Nadège Dossoumou who were a blessing to work with and who ensured the success of the empirical field research through an excellent collaborative effort. Then, Dr. David Daou and Dr. Guido Lüchters for their endless encouragement and voluntary mentorship. Dr. Rholan Houngue, Maxime Rushemuka, Lorina Schudel and Victor Kpokpoya for always being helpful and supportive in times of need. Sinja Buri for enabling me to conclude my research alongside gaining valuable project experience. Katja Reinicke for her encouragement for tackling the writing phase. Also, I highly appreciate the collaboration with the West African Science Center for Climate Change and Adapted Land Use (WASCAL) in Lomé and Abomey-Calavi and would like to thank especially Prof. Dr. Julien Adounkpè, Prof. Dr. Prosper Begedou, Dr. Kossi Komi, the team of field interviewers as well as the participants who agreed to be part of this research. Moreover, the support of my family and friends helped me to remain committed and enduring. I would like to say special thanks to my family as well as to Kehinde, Ruth, Lili, Sally, Timo, Kariuki, Hannah, Daniel, Simone, Kudzai, Fabian, Gregor, Lukas and Stefan who have always been there for me to talk, spend time together, taking trips, making music and helped me to keep a balance in life. And finally, I would like to thank my wife and soulmate Everjoy for her never-ending love and support. It has been the greatest blessing to go through this process by your side and hand in hand.

Table of contents

List of figures

List of tables

List of publications

Systematic review article (Peer reviewed)

Wagner, S., Souvignet, M., Walz, Y. et al. *When does risk become residual? A systematic review of research on flood risk management in West Africa.* Regional Environmental Change 21, 84 (2021). https://doi.org/10.1007/s10113-021-01826-7

Empirical research article 1 (Peer reviewed)

Wagner S, Thiam S, Dossoumou NIP, Hagenlocher M, Souvignet M, Rhyner J. *Recovering from Financial Implications of Flood Impacts—The Role of Risk Transfer in the West African Context.* Sustainability. 2022; 14(14):8433. https://doi.org/10.3390/su14148433

Empirical research article 2 (Peer-reviewed)

Wagner, S., Thiam, S.; Dossoumou, N.; Daou, D. *What influences the demand for a potential flood insurance product in an area with low previous exposure to insurance? – a case study in the West African Lower Mono River Basin (LMRB).* Economics of Disasters and Climate Change 8, 1–32 (2024). https://doi.org/10.1007/s41885-023-00138-w

Discussion paper (Not peer-reviewed)

Wagner, S. *The potential role of Insurance in flood adaptation – A case study of the transboundary Lower Mono River Basin (LMRB) shared between Togo and Benin*. MCII Discussion Paper Series August 2022. Accessible via: https://climate-insurance.org/wp-content/uploads/2022/11/MCII_set_of_conclusions_FINAL_Nov-22.pdf (last access 22/03/2023).

Abbreviations

ADRiFi	Africa Disaster Risks Financing
AJOL	African Journals Online
BCE	Björnsen Consulting Engineers GmbH
BMBF	Federal Ministry of Education and Research
CDRFI	Climate and Disaster Risk Finance
CLIMAFRI	Implementation of Climate-sensitive Adaptation Strategies to Reduce the Flood Risk in the Catchment Area of the Cross-border Lower Mono River
CM	Clubs des Mères
COP	Conference of the Parties
DL	Deep Learning
DRF	Disaster Risk Financing
DRFI	Disaster Risk Financing and Insurance
DRR	Disaster Risk Reduction
EM-Dat	The Emergency Events Database
ECOWAS	Economic Community of West African States
EVES	Environmental Vulnerability & Ecosystem Services Section
FRM	Flood Risk Management
G7	Group of Seven
GCMs	Global Climate Models
GLM	Generalized Linear Model
HFA	Hyogo Framework for Action
IGP	InsuResilience Global Partnership
IPCC	Intergovernmental Panel on Climate Change
IRFF	Insurance and Risk Finance Facility

MCII	Munich Climate Insurance Initiative
ML	Machine Learning
NFIP	National Flood Insurance Programme
NGOs	Non-Governmental Organizations
L&D	Loss and Damage
LECZ	Low-Elevation Coastal Zones
LMRB	Lower Mono River Basin
PACET	Pan African Cooperation and Educational Technologies
PCA	Principal Component Analysis
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCMs	Regional Climate Models
SEM	Structural Equation Model
SFDRR	Sendai Framework for Disaster Risk Reduction
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNU-EHS	United Nations University – Institute for Environment and Human Security
V20	The Vulnerable Twenty
VARMAP	Vulnerability Assessment, Risk Management & Adaptive Planning Section
WASCAL	West African Science Center for Climate Change and Adapted Land Use
ZEF	Center for Development Research

1. Introduction

1.1 Introduction

In the West African region, floods have been a prevailing problem for a long time, with an intensification of the problem in the past two decades (Hounkpè et al. 2022). Recorded riverine flood events alone have affected around 17 million people in West Africa over the past 30 years, with particularly devastating events taking place in Nigeria (e.g., 2012 & 2010), Benin & Togo (e.g., 2010), Niger (e.g., 2012), and Ghana (e.g., 2007) (EM-DAT 2022, United Nations 2010). Floods usually cause widespread damage, such as damage to buildings, infrastructure, agriculture, environment and health, as well as livelihoods and businesses (World Food Programme 2022, Kouamé et al. 2022, Guardian 2022). In addition, climatic trends are projected to exacerbate precipitation extremes in the coastal areas even further, leading to more intense flood and drought events (Ndehedehe et al. 2022, Dunning et al. 2018). Aside from climatic factors, the trend of increasing riverine floods can also be associated with further aspects, such as increased and more systematic recording of flood events (Schendel and Thongwichian 2017), settlement expansion/ increasing number of inhabitants in exposed areas (Yiwo et al. 2022, Parkoo et al. 2022, Güneralp et al. 2020, Güneralp et al. 2015), deforestation, and modification of river systems (Parkoo et al. 2022, Mahe et al. 2013). With regards to those trends, West African river basins, such as the Mono River Basin are of substantial interest to flood risk-related research in order to navigate the challenges that are expected from the outlined developments.

Moreover, in light of such increasingly severe and frequent extreme flood events, the need for adaptation to the changing risk levels and circumstances arises. The Intergovernmental Panel on Climate Change (IPCC) describes adaptation for human systems as *"the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities"* (IPCC 2023, p.2898). This process also relates to the adjustment of conventional risk management practices beyond the current scope due to its capacities being increasingly exceeded. Risk management in the context of disasters aims *"to improve the understanding of current and future disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, prevention and protection, response and recovery practices […]"* (IPCC 2023, p.2906). It is assumed that despite measures and efforts to reduce risk levels, a certain share of disaster risk, termed as residual risk, remains unmanaged (UNDRR 2023a, Schinko et al. 2019). The reasons for its existence are diverse. The risk can remain present, due to, for example limited risk awareness (Fox-Rogers et al. 2016, Ludy and Kondolf 2012), lack of coordination between public actors the subsequent development of buildings in flood-prone areas (Fu et al. 2023), varying ways of authorities taking residual risk into account (Serra-Llobet et al. 2022), risk levels being socially tolerated (Dow et al.

2013), the expected costs for risk-reduction being higher than the expected cost from the damage (Bouwer 2019) or limited efforts/capacities to reduce disaster risk (United Nations 2015). One of several ways of managing residual risk is through practicing risk transfer, which, according to the United Nations Office for Disaster Risk Reduction (UNDRR), describes *"the process of formally or informally shifting the financial consequences of particular risks from one party to another, whereby a household, community, enterprise or State authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party"* (UNDRR 2023b, n.p.). While informal risk transfer can occur within social settings of families or communities (UNDRR 2023b), possible types of formal risk transfer encompass for example sovereign (insurance) risk pools, CAT bonds, or insurance on the meso-/micro level or for public assets (Cissé 2021). Risk transfer through insurance has become an established component in flood risk management approaches of several developed economies (Seifert-Dähnn 2018, Surminski and Eldridge 2017). Also, the suitability for the application of insurance in the context of managing impacts from climate-related extreme events has been discussed in the context of developing economies, however more controversially (Mechler et al. 2019, Schaefer et al. 2016, Surminski and Oramas-Dorta 2014, Warner et al. 2012).

Within the latter debate, often closely connected to the topic of Loss and Damage (L&D), it is frequently raised that high-income countries that emit high levels of greenhouse gases, could take more financial responsibility to finance compensation mechanisms for impacts arising from more frequent and severe climate-related disasters that are seen to disproportionally affect developing economies (Mechler et al. 2019). At the Conference of the Parties (COP) 27 in 2022 the "Global Shield" was launched by the Group of Seven (G7) and the Vulnerable Twenty (V20) member states as a mechanism in which wealthy countries pay for or support financial instruments from the realm of Climate and Disaster Risk Finance and Insurance (CDRFI), such as insurance, for vulnerable low-income countries to provide a form of compensation for climate-related losses and damages (Federal Ministry for Economic Cooperation and Development 2022). Also, prior to the "Global Shield" there have been initiatives revolving around leveraging the insurance coverage of vulnerable low-income countries, such as the InsuResilience Global Partnership (IGP). One of the central aims of the IGP is to raise the number of people from vulnerable and poor countries covered by CDRFI mechanisms to 500 million by the year 2025 by drawing upon the support of actors from the public and also the private sector, e.g., credit and insurance providers (InsuResilience Global Partnership 2021). Moreover, the topic of insurance has been taken up by various development finance organisations such as the Insurance and Risk Finance Facility (IRFF) at the United Nations Development Programme (UNDP 2021), the Disaster Risk Financing and Insurance (DRFI) program at the World Bank (World Bank n.d.) or the Africa Disaster

Risks Financing (ADRiFi) Programme at the African Development Bank (African Development Bank 2018).

Nevertheless, there are fundamental critiques to insurance, which is market-based in most cases – unless subsidized, to address the impacts and risks of the population in developing economies that are vulnerable and exposed to natural hazards compounded by rising levels of climatic changes. In the scientific communities of L&D, risk management or adaptation several points are being raised in discussions on its application for households or individuals. Dehm (2020), for example, argues that by focusing the debate on market-based instruments such as insurance, responsibility to pay for the cost of economic losses and damages is shifted away from the polluting parties to the vulnerable countries. That aspect has to be additionally reflected with regard to market-based insurance premiums having profit margins that are added to the annual expected loss (Linnerooth-Bayer et al. 2019). In addition, Lucas and Booth (2020) argue that the pursuit of market-based disaster financing tools, such as insurance, lead to a shift away from a solidaric and collective responsibility approach of the government to an individualistic approach in which people are responsible themselves to cover for disaster impacts, which however excludes the most vulnerable due to high premiums. Moreover, Pill (2022) states that a "polluter pays principle" should apply, which holds the polluting party liable to pay for environmental damages associated with their emissions. Further common critics of insurance approaches, also of those that are voluntarily subsidized by high-income countries, are put forward by Gewirtzman et al. (2018) that such subsidizing contributions are often irregular and unreliable and also that they do not cover a wide range of climate-related hazards such as slow-onset events (e.g., sea level rise) or non-economic impacts (e.g., ecosystem-losses).

Contrarily, there role of risk transfer and insurance, in parts as market-based risk finance, is raised as a crucial component of leveraging finance for climate-related impacts and risks in several ways (Mechler and Deubelli 2021, Konrad and Thum 2012). In general, insurance is seen to be best suited for addressing hazard events that occur in medium to high intensity, however in rare frequency, also described as the medium risk layer in Disaster Risk Financing (DRF) (Linnerooth-Bayer and Hochrainer-Stigler 2015, Ghesquiere and Mahul 2010). Moreover, Linnerooth-Bayer et al. (2019) argue that, aside protecting public budgets in times of disaster, insurance allows for a more reliable and rapid source of post-disaster liquidity than other forms of disaster risk financing, such as public assistance, humanitarian aid or remittances, and thus better helps to avoid other cascading impacts that can arise out of coping with the financial needs after experiencing a disaster, such as selling productive assets or taking children out of school. In addition, insurance can have the potential to trigger risk-reducing behavior through setting incentives that reward such actions (Schäfer et al. 2019). Finally, Nur et al. (2017) raise that there can be three advantages (dividends) arising from the application of insurance

in the context of disaster risk reduction: (1) Directly compensating disaster victims financially and avoiding long-term adverse financial implications, (2) potentially fostering economic growth through incentivizing risk-taking by reducing disaster risk in an actual or a potential manner, and (3) wider co-benefits for society, relating to the well-being of individuals and accounatbility in politics.

In that way, there are two significantly different lines of argumentation – one that emphasizes the importance of insurance, partly as a market-based instrument, and the other one that challenges the suitability of its application for climate-related impacts and risks in developing economies.

Concerning the already long lasting prevalence of flood-related issues in West Africa and their perceived increasing intensity and frequency, a wide range of studies has been conducted that approached the topic from different angles. Previous flood risk-related research in West Africa espcially focused on creating risk and vulnerability profiles to flood events (Oyedele et al. 2022, Amoako and Inkoom 2018, Macnight Ngwese et al. 2018, Asare-Kyei et al. 2017, Ntajal et al. 2017, Yankson et al. 2017, Kablan et al. 2017, Salami et al. 2017, Derbile et al. 2016, Olokesusi et al. 2015, Kissi et al. 2015, Adelekan and Fregene 2015, Adelekan 2011, 2010), flood risk perception (Abu and Codjoe 2018, Schlef et al. 2018, Onwuemele 2018, Ahadzie et al. 2016, Adelekan and Asiyanbi 2016, Codjoe and Afuduo 2015, Ajibade et al. 2013, Fossi et al. 2012), and actions that aim at adaptation and hazard mitigation in general (Amoako 2018, Boubacar et al. 2017, Ahadzie et al. 2016, Codjoe and Issah 2016, Odemerho 2015, Ezemonye and Emeribe 2014, Kloos and Renaud 2014, Campion and Venzke 2013, Oyekale et al. 2013). In comparison, studies which put the main emphasis on how people cope with the adverse financial impacts of flood events or what risk transfer options they draw upon to address residual flood risk and how they navigate the financial recovery process marks an exception and seem to pick up only recently. In particular, the potential role of insurance as a mean of flood adaptation remains to be systematically discussed in this context yet. Studies have been conducted on rice farmer's preferences in the Volta River Basin in Ghana to purchase flood insurance under monetary and non-monetary payment methods (Navrud and Vondolia 2020), on the need of Northern Nigerian farmers to get access to credit to deal with adverse impacts from floods and other climate change impacts (Abraham and Fonta 2018). Or also, on how household assets, such as human health, financial savings, housing, and farmlands were vulnerable to flooding in central rural Ghana (Afriyie et al. 2018).

Despite the presence of the studies mentioned above, none of them has considered the established practices on the ground to deal with the financial implications of floods and assessed the potential of flood insurance. In that context, the informal aspect of risk transfer (UNDRR 2023b) and in a more overarching manner the diverse ways of financial coping in disaster situations gain high importance.

Coping is seen as “the use of available skills, resources and opportunities to address, manage and overcome adverse conditions, with the aim of achieving basic functioning of people, institutions, organisations and systems in the short to medium term” (IPCC 2023, p.2904). Thus, when households do not have widespread access to formal options for risk transfer, they will have to find ways of coping financially, which can include finding ways of setting up informal risk transfer arrangements. It will be of high relevance to further elaborate on the relationship between such the presence of such practices and the financial recovery time of households from flood impacts. Also, it is necessary to provide insights into the characteristics (if they qualify as informal risk transfer) and the level of sufficiency of those existing options that are available to the population for financial coping. Thereby, it is important to assess their suitability for addressing flood impacts with regards to the previously mentioned projected climatic changes for the West African region. Also, in consideration of the previously mentioned debate on potential the role of insurance in the context of developing economies, it is thus relevant to empirically research the actual flood impacts that put people into the position of a financial need. In addition to that, research focussing on the uptake of insurance against floods found that various aspects such as the disposable household income, the level of understanding of insurance, the types of covered risks, levels of trust, the level of flood risk and perceptions on it as well as perceptions on responsibilities for damage prevention can be potentially influential in a household’s decision (e.g., Huang and Lubell 2022, Oduniyi et al. 2020, Reynaud et al. 2018, Arshad et al. 2016, Oulahen 2015, Aliagha et al. 2014, Seifert et al. 2013, Botzen and van den Bergh 2012, Kunreuther and Pauly 2004). Furthermore, households might also be interested in insurance products due to the absence of other reliable means to alleviate the damage (such as compensation or relief aid from public actors or NGOs) (Linnerooth-Bayer et al. 2019) or due to the inability of own savings or local risk-sharing to cater for large scale events to protect themselves and their livelihoods (Germanwatch & MCII 2020). Influential factors for flood insurance demand can be very context-specific and require an approach that is able to incorporate those aspects. As a consequence, it will be also important to explore the interest levels of households at risk with regards to a potential insurance product, especially in contexts where the population at risk has not been widely making experiences with and using insurance products before. To further shed light on the outlined aspects, the empirical research conducted within the scope of this Ph.D. project is going to focus on the potential role of insurance in the case study of the Lower Mono River Basin (LMRB) shared between Togo and Benin in West Africa.

1.2 Background of the research project

The Ph.D. research presented here was conducted in the scope of a project titled “Implementation of Climate-sensitive Adaptation Strategies to Reduce the Flood Risk in the Catchment Area of the Cross-border Lower Mono River” (CLIMAFRI). The project targets the Lower Mono River Basin (LMRB), shared between Togo and Benin in West Africa (Figure 3.1). Floods in the LMRB currently occur on a frequent basis, usually causing widespread damage to agriculture, buildings infrastructure and livelihoods (FloodList 2019). The southern area of West Africa, in which the LMRB is located, has two periods per year that qualify as the rainy season between April and the middle of July as well as again between September and October (Rameshwaran et al. 2021). Results from studies focusing on climate modeling in the area vary depending on the model type. However, they generally project a shift towards later rainy seasons, more extreme precipitation events and more pronounced extreme conditions, such flood and drought events (Amoussou et al. 2020, Lamboni et al. 2019).

The objective of this Federal Ministry of Education and Research (BMBF)-funded project was to be involved in co-developing and co-implementing adaptation strategies with local stakeholders to achieve the sustainable management of flood risk as well as environmental resources in the transboundary Lower Mono River basin (LMRB). Several project partners were involved. From the German side, the partners consisted of the working group Eco-Hydrology and Water Resources Management located at the University of Bonn, the Center for Development Research (ZEF) located at the University of Bonn, the engineering company Björnsen Consulting Engineers GmbH (BCE), the Department of Intercultural German Studies located at the University of Bayreuth, the United Nations University – Institute for Environment and Human Security (UNU-EHS) and its three sections Environmental Vulnerability & Ecosystem Services Section (EVES), Pan African Cooperation and Educational Technologies (PACET), Munich Climate Insurance Initiative (MCII), and Vulnerability Assessment, Risk Management & Adaptive Planning Section (VARMAP). From the Beninese and Togolese side, the partners included the West African Science Center for Climate Change and Adapted Land Use (WASCAL) in Lomé (Togo) and Abomey-Calavi (Benin), the University of Lomé, the University of Abomey-Calavi, the Ministry of Environment and Forest Resources in Togo, and the Ministry of Living Environment and Sustainable Development in Benin. The overall objective of the project was to improve both flood risk management and water management through the implementation of a river basin information system in accompaniment of a catalogue with potential options for customization as well as a set of recommendations with regards to insurance as potential form of risk transfer (BMBF 2019).

The specific contribution on the potential role of insurance in flood adaptation was conducted within MCII. The central aim of this part of CLIMAFRI and the Ph.D. project was to provide a comprehensive picture about the current situation in the LMRB relating to the feasibility of insurance based on both literature and empirical insights. Thus, this study has the overall objective of exploring the potential of insurance as a flood risk management strategy for at risk-households in the Lower Mono River Basin shared between Togo and Benin. The overall objective is broken down into the following three sub-objectives:

1. To review previous research results on the common flood impacts and types of risk management activities in the West African region to obtain a background on the current and potential role of insurance in the research context
2. To assess the prevalence and sufficiency of existing ways of financial coping
3. To elaborate the explicit demand for a potential flood insurance product among the at risk-population

Based on an initial field visit and scoping of literature, hypotheses were formulated to complement the research objectives and to additionally guide the research activities:

1. Currently, floods are frequently treated from a perspective of flood control with an emphasis on structural measures and limited options for (formal) risk transfer

2. Existing ways of financial coping are not adequate to the magnitude and frequency of the impacts and mostly in an informal, small-scale risk pool

3. The explicit demand for insurance is more determined by factors relating to interaction with institutions (government, NGO, social environment) and factors related to the interaction with insurance (e.g., perception, trust, level of understanding) than by levels of actual and perceived flood risk

1.3 Structure of the dissertation

This dissertation project is structured in the following way. Chapter 1 provides an introduction to the context of research on and policies for insurance in the context of managing flood risks. Moreover, detailed background information on the research area and the research project itself are provided in this chapter. Finally, the structure of the dissertation and the reasons behind are outlined.

Furthermore, in chapter 2, this dissertation initially produced research on lessons that can be drawn from research trends in the management of common flood impacts in the West African context.

Therefore, a systematic literature review was conducted (publication 1), that explored common flood risk management activities (both practiced and recommended) and flood impacts as they were reported in peer-reviewed literature. This study was performed to inform the empirical work and to embed it into the broader flood risk management paradigm of the region. In addition, it gave a first impression on the central question of the potential role of insurance as a flood risk management tool in the Lower Mono River basin for targeted households. Moreover, it also helped to shape the categories used in empirical data collection later on, especially when inquiring about the types of flood impacts on households in the research area. The latter aspect, was then further explored in-depth by workshops, semi-structured interviews and the household survey and was reported in publication 2.

In chapter 3, the aspect of impacts with financial flood implications guided the assessment of the sufficiency of existing risk transfer mechanisms to alleviate and cope with those types of flood impacts. The study assesses how frequent and severe such categories impacts arise on average. Besides, it is central to this publication, which financial coping mechanisms households currently have access to, to deal with the financial needs arising from flood impacts. It is of additional interest to see whether the existing means of financial coping can be classified as risk transfer mechanisms or not. Finally, this study is going to shed light on the association between the presence of those mechanisms and the duration of financial recovery time. In that way, a statement on the sufficiency of the existing mechanisms in relation to the impacts can be produced.

Besides in chapter 4, the explicit demand of households at risk for insurance was researched. Here, influential parameters for the insurance demand for a potential insurance product are seen as a central aspect in researching this question. Therefore, a framework for parameter selection was derived from findings of empirical studies centered around the terms of willingness to pay and willingness to insure. Furthermore, it is tested which model type achieves the highest accuracy in predicting the demand for a potential flood insurance product. In doing this different machine learning (incl. deep learning models) types are compared. Finally, the level of influence of various parameters from the household survey data set will be portrayed the feature importance. This is done for the most accurate model – a sequential neural network model. A detailed graphical overview on the relation between the publications and research questions is provided in Figure 1.1.

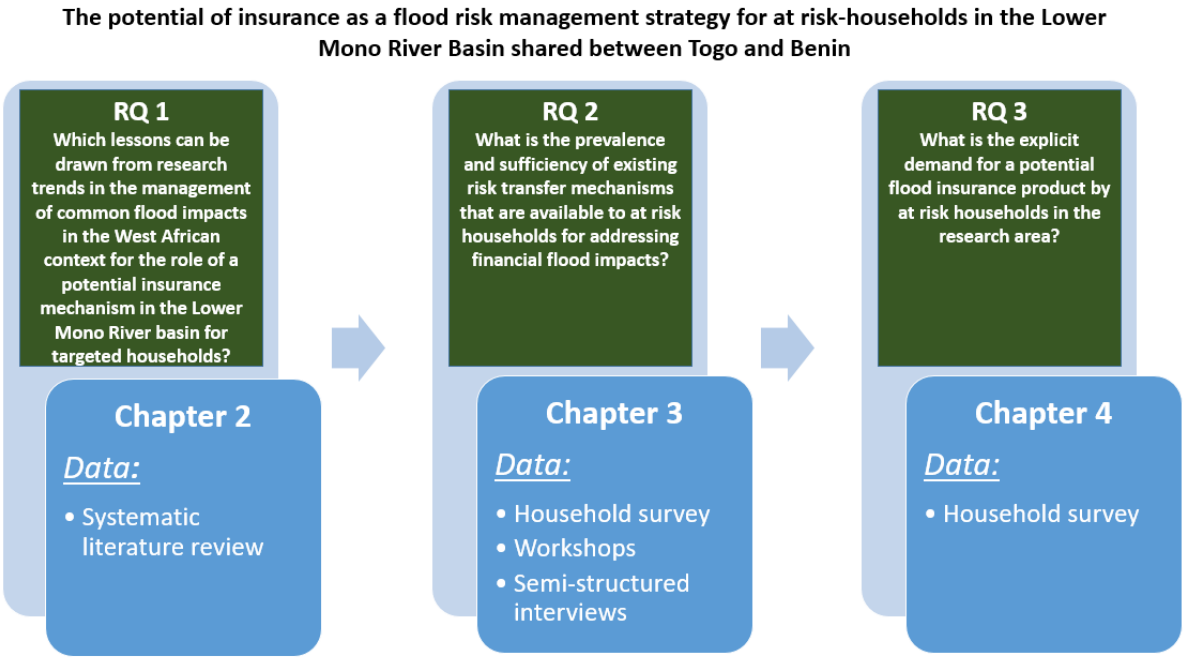


Figure 1.1: Visualization of research questions and methods

Q 1. Which lessons can be drawn from research trends in the management of common flood impacts in the West African context for the role of a potential insurance mechanism in the Lower Mono River basin for targeted households?

Q 1.1 What are research trends regarding practiced flood risk management in the West African region? *(Systematic literature review)*

Q 1.2 What are research trends regarding recommended flood risk management in the West African region? *(Systematic literature review)*

Q 1.3 Which flood impacts are households in the research area experiencing? *(Systematic literature review)*

Q 2. What is the prevalence and sufficiency of existing risk transfer mechanisms that are available to at risk households for addressing financial flood impacts?

Q 2.1 Which flood impacts put households in the research area into a position of financial need? *(Workshops, semi-structured interviews, household survey)*

Q 2.2 What are characteristics (frequency, severity) of the flood impacts with financial implications on the households? *(Household survey)*

Q 2.3 Which financial coping mechanisms do targeted households currently have access to deal with the financial needs arising from flood impacts and what are their characteristics? *(Workshops, semi-structured interviews, household survey)*

Q 2.4 What is the association between the presence of mechanisms and the duration of recovery time from financial flood impacts? *(Household survey)*

Q 3. What is the explicit demand for a potential flood insurance product by at risk households in the research area?

Q 3.1 Which parameters emerge as relevant for the demand for a potential flood insurance product based on a data-driven selection process? *(Household survey)*

Q 3.2 Which model type best predicts the demand of households for a potential flood insurance product? *(Household survey)*

Q 3.3 What are the most influential parameters in predicting the purchase likelihood consist for a potential flood insurance product? *(Household survey)*

After, the empirical research has been presented in the previous sections, chapter 5 provides a summarizing discussion of all empirical research and puts it into perspective. Finally, final conclusions that summarize key messages of the research project and that generate lessons for further research and practitioners will be drawn in chapter 6.

1.4 References

References

Abraham TW, Fonta WM (2018) Climate change and financing adaptation by farmers in northern Nigeria. Financ Innov 4. doi: 10.1186/s40854-018-0094-0

Abu M, Codjoe SNA (2018) Experience and Future Perceived Risk of Floods and Diarrheal Disease in Urban Poor Communities in Accra, Ghana. Int J Environ Res Public Health 15. doi: 10.3390/ijerph15122830

Adelekan I, Fregene T (2015) Vulnerability of artisanal fishing communities to flood risks in coastal southwest Nigeria. Climate and Development 7:322–338. doi: 10.1080/17565529.2014.951011

Adelekan IO (2010) Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. Environment and Urbanization 22:433–450. doi: 10.1177/0956247810380141

Adelekan IO (2011) Vulnerability assessment of an urban flood in Nigeria: Abeokuta flood 2007. Nat Hazards 56:215–231. doi: 10.1007/s11069-010-9564-z

Adelekan IO, Asiyanbi AP (2016) Flood risk perception in flood-affected communities in Lagos, Nigeria. Nat Hazards 80:445–469. doi: 10.1007/s11069-015-1977-2

African Development Bank (2018) African Development Bank rolls out programme to boost climate risk financing and insurance for African countries. https://www.afdb.org/en/news-and-events/african-development-bank-rolls-out-programme-to-boost-climate-risk-financing-and-insurance-for-african-countries-18618. Accessed 13 Oct 2023

Afriyie K, Ganle JK, Santos E (2018) 'The floods came and we lost everything': weather extremes and households' asset vulnerability and adaptation in rural Ghana. Climate and Development 10:259–274. doi: 10.1080/17565529.2017.1291403

Ahadzie DK, Dinye I, Dinye RD, Proverbs DG (2016) Flood risk perception, coping and management in two vulnerable communities in Kumasi, Ghana. Int. J. SAFE 6:538–549. doi: 10.2495/SAFE-V6-N3-538-549

Ajibade I, McBean G, Bezner-Kerr R (2013) Urban flooding in Lagos, Nigeria: Patterns of vulnerability and resilience among women. Global Environmental Change 23:1714–1725. doi: 10.1016/j.gloenvcha.2013.08.009

Aliagha UG, Jin TE, Choong WW, Nadzri Jaafar M, Ali HM (2014) Factors affecting flood insurance purchase in residential properties in Johor, Malaysia. Nat. Hazards Earth Syst. Sci. 14:3297–3310. doi: 10.5194/nhess-14-3297-2014

Amoako C (2018) Emerging grassroots resilience and flood responses in informal settlements in Accra, Ghana. GeoJournal 83:949–965. doi: 10.1007/s10708-017-9807-6

Amoako C, Inkoom DKB (2018) The production of flood vulnerability in Accra, Ghana: Re-thinking flooding and informal urbanisation. Urban Studies 55:2903–2922. doi: 10.1177/0042098016686526
Amoussou E, Awoye H, Totin Vodounon HS, Obahoundje S, Camberlin P, Diedhiou A, Kouadio K, Mahé G, Houndénou C, Boko M (2020) Climate and Extreme Rainfall Events in the Mono River Basin (West Africa): Investigating Future Changes with Regional Climate Models. Water 12:833. doi: 10.3390/w12030833
Arshad M, Amjath-Babu TS, Kächele H, Müller K (2016) What drives the willingness to pay for crop insurance against extreme weather events (flood and drought) in Pakistan? A hypothetical market approach. Climate and Development 8:234–244. doi: 10.1080/17565529.2015.1034232
Asare-Kyei D, Renaud FG, Kloos J, Walz Y, Rhyner J (2017) Development and validation of risk profiles of West African rural communities facing multiple natural hazards. PLoS One 12:e0171921. doi: 10.1371/journal.pone.0171921
BMBF (2019) CLIMAFRI – Implementing climate-sensitive adaptation strategies to reduce flood risks. Client II – International partnerships for sustainable innovations, Bonn, Germany
Botzen W, van den Bergh J (2012) Risk attitudes to low-probability climate change risks: WTP for flood insurance. Journal of Economic Behavior & Organization 82:151–166. doi: 10.1016/j.jebo.2012.01.005
Boubacar S, Pelling M, Barcena A, Montandon R (2017) The erosive effects of small disasters on household absorptive capacity in Niamey: a nested HEA approach. Environment and Urbanization 29:33–50. doi: 10.1177/0956247816685515
Bouwer LM (2019) Observed and Projected Impacts from Extreme Weather Events: Implications for Loss and Damage. In: Mechler R, Bouwer LM, Schinko T, Surminski S, Linnerooth-Bayer J (eds) Loss and Damage from Climate Change. Springer International Publishing, Cham, pp 63–82
Campion BB, Venzke J-F (2013) Rainfall variability, floods and adaptations of the urban poor to flooding in Kumasi, Ghana. Nat Hazards 65:1895–1911. doi: 10.1007/s11069-012-0452-6
Cissé JD (2021) Climate and Disaster Risk Financing Instruments: An Overview, Bonn, Germany
Codjoe SNA, Afuduo S (2015) Geophysical, socio-demographic characteristics and perception of flood vulnerability in Accra, Ghana. Nat Hazards 77:787–804. doi: 10.1007/s11069-015-1624-y
Codjoe SNA, Issah AD (2016) Cultural dimension and adaptation to floods in a coastal settlement and a savannah community in Ghana. GeoJournal 81:615–624. doi: 10.1007/s10708-015-9641-7
Dehm J (2020) Climate change, 'slow violence' and the indefinite deferral of responsibility for 'loss and damage'. Griffith Law Review 29:220–252. doi: 10.1080/10383441.2020.1790101
Derbile EK, File DJM, Dongzagla A (2016) The double tragedy of agriculture vulnerability to climate variability in Africa: How vulnerable is smallholder agriculture to rainfall variability in Ghana? Jamba 8:249. doi: 10.4102/jamba.v8i3.249
Dow K, Berkhout F, Preston BL (2013) Limits to adaptation to climate change: a risk approach. Current Opinion in Environmental Sustainability 5:384–391. doi: 10.1016/j.cosust.2013.07.005
Dunning CM, Black E, Allan RP (2018) Later Wet Seasons with More Intense Rainfall over Africa under Future Climate Change. J. Climate 31:9719–9738. doi: 10.1175/JCLI-D-18-0102.1
EM-DAT (2022) The Emergency Events Database. https://www.emdat.be/emdat_db/. Accessed 15 Nov 2022
Ezemonye MN, Emeribe CN (2014) Flooding and Household Preparedness in Benin City, Nigeria. MJSS. doi: 10.5901/mjss.2014.v5n1p547
Federal Ministry for Economic Cooperation and Development (2022) V20 and G7 agree on financial protection cooperation, to formally launch Global Shield against Climate Risks at COP27. https://www.bmz.de/en/news/press-releases/v20-g7-agree-launch-global-shield-against-climate-risks-cop27-125782. Accessed 11/22/2022
FloodList (2019) Togo and Benin – Mono River Flooding Affects 50,000. https://floodlist.com/africa/togo-benin-mono-river-floods-october-november-2019. Accessed 06 Feb 2023
Fossi S, Barbier B, Brou YT, Kodio A, Mahé G (2012) Perception sociale de la crue et réponse des pêcheurs à la baisse de l'inondation des plaines dans le Delta Intérieur du Niger, Mali. tem:55–72. doi: 10.4000/tem.1739
Fox-Rogers L, Devitt C, O'Neill E, Brereton F, Clinch JP (2016) Is there really "nothing you can do"? Pathways to enhanced flood-risk preparedness. Journal of Hydrology 543:330–343. doi: 10.1016/j.jhydrol.2016.10.009
Fu X, Bell R, Reu Junqueira J, White I, Serrao-Neumann S (2023) Managing rising residual flood risk: A national survey of Aotearoa-New Zealand. J Flood Risk Management. doi: 10.1111/jfr3.12944
Germanwatch & MCII (2020) Climate Risk Insurance and Informal Risk-Sharing: A Critical Literature Appraisal.
Gewirtzman J, Natson S, Richards J-A, Hoffmeister V, Durand A, Weikmans R, Huq S, Roberts JT (2018) Financing loss and damage: reviewing options under the Warsaw International Mechanism. Climate Policy 18:1076–1086. doi: 10.1080/14693062.2018.1450724
Ghesquiere F, Mahul O (2010) Financial Protection of the State against Natural Disasters. A Primer. Policy Research Working Paper
Guardian (2022) After the floods: Picking bits, pieces of ruined investments, livelihoods. Guardian Nigeria
Güneralp B, Güneralp İ, Liu Y (2015) Changing global patterns of urban exposure to flood and drought hazards. Global Environmental Change 31:217–225. doi: 10.1016/j.gloenvcha.2015.01.002

Güneralp B, Reba M, Hales BU, Wentz EA, Seto KC (2020) Trends in urban land expansion, density, and land transitions from 1970 to 2010: a global synthesis. Environ. Res. Lett. 15:44015. doi: 10.1088/1748-9326/ab6669

Hounkpè J, Badou DF, Ahouansou DMM, Totin E, Sintondji LOC (2022) Assessing observed and projected flood vulnerability under climate change using multi-modeling statistical approaches in the Ouémé River Basin, Benin (West Africa). Reg Environ Change 22. doi: 10.1007/s10113-022-01957-5

Huang C, Lubell M (2022) Household flood risk response in San Francisco Bay: linking risk information, perception, and behavior. Reg Environ Change 22. doi: 10.1007/s10113-022-01875-6

InsuResilience Global Partnership (2021) InsuResilience Global Partnership Vision 2025. Reviewed version July 2021

IPCC (2023) Annex II: Glossary [Möller, V., van Diemen, R., Matthews, J.B.R., Méndez, C., Semenov, S., Fuglestvedt, J.S., Reisinger, A. (eds.)]. In: Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., Rama, B. (ed) Climate Change 2022 – Impacts, Adaptation and Vulnerability. Cambridge University Press, pp 2897–2930

Kablan MKA, Dongo K, Coulibaly M (2017) Assessment of Social Vulnerability to Flood in Urban Côte d'Ivoire Using the MOVE Framework. Water 9:292. doi: 10.3390/w9040292

Kissi AE, Abbey GA, Agboka K, Egbendewe A (2015) Quantitative Assessment of Vulnerability to Flood Hazards in Downstream Area of Mono Basin, South-Eastern Togo: Yoto District. JGIS 07:607–619. doi: 10.4236/jgis.2015.76049

Kloos J, Renaud FG (2014) Organic Cotton Production as an Adaptation Option in North-West Benin. Outlook Agric 43:91–100. doi: 10.5367/oa.2014.0166

Konrad KA, Thum M (2012) The Role of Economic Policy in Climate Change Adaptation. EIB Working Papers 2

Kouamé PK, Fokou G, Koffi AJd, Sani A, Bonfoh B, Dongo K (2022) Assessing Institutional Stakeholders' Perception and Limitations on Coping Strategies in Flooding Risk Management in West Africa. Int J Environ Res Public Health 19. doi: 10.3390/ijerph19116933

Kunreuther H, Pauly M (2004) Neglecting Disaster: Why Don't People Insure Against Large Losses? Journal of Risk and Uncertainty 28:5–21. doi: 10.1023/B:RISK.0000009433.25126.87

Lamboni B, Emmanuel LA, Manirakiza C, Djibib ZM (2019) Variability of Future Rainfall over the Mono River Basin of West-Africa. AJCC 08:137–155. doi: 10.4236/ajcc.2019.81008

Linnerooth-Bayer J, Hochrainer-Stigler S (2015) Financial instruments for disaster risk management and climate change adaptation. Climatic Change 133:85–100. doi: 10.1007/s10584-013-1035-6

Linnerooth-Bayer J, Surminski S, Bouwer LM, Noy I, Mechler R (2019) Insurance as a Response to Loss and Damage? In: Mechler R, Bouwer LM, Schinko T, Surminski S, Linnerooth-Bayer J (eds) Loss and Damage from Climate Change. Springer International Publishing, Cham, pp 483–512

Lucas CH, Booth KI (2020) Privatizing climate adaptation: How insurance weakens solidaristic and collective disaster recovery. WIREs Clim Change 11. doi: 10.1002/wcc.676

Ludy J, Kondolf GM (2012) Flood risk perception in lands "protected" by 100-year levees. Nat Hazards 61:829–842. doi: 10.1007/s11069-011-0072-6

Macnight Ngwese N, Saito O, Sato A, Agyeman Boafo Y, Jasaw G (2018) Traditional and Local Knowledge Practices for Disaster Risk Reduction in Northern Ghana. Sustainability 10:825. doi: 10.3390/su10030825

Mahe G, Lienou G, Descroix L, Bamba F, Paturel JE, Laraque A, Meddi M, Habaieb H, Adeaga O, Dieulin C, Chahnez Kotti F, Khomsi K (2013) The rivers of Africa: witness of climate change and human impact on the environment. Hydrol. Process. 27:2105–2114. doi: 10.1002/hyp.9813

Mechler R, Calliari E, Bouwer LM, Schinko T, Surminski S, Linnerooth-Bayer J, Aerts J, Botzen W, Boyd E, Deckard ND, Fuglestvedt JS, González-Eguino M, Haasnoot M, Handmer J, Haque M, Heslin A, Hochrainer-Stigler S, Huggel C, Huq S, James R, Jones RG, Juhola S, Keating A, Kienberger S, Kreft S, Kuik O, Landauer M, Laurien F, Lawrence J, Lopez A, Liu W, Magnuszewski P, Markandya A, Mayer B, McCallum I, McQuistan C, Meyer L, Mintz-Woo K, Montero-Colbert A, Mysiak J, Nalau J, Noy I, Oakes R, Otto FEL, Pervin M, Roberts E, Schäfer L, Scussolini P, Serdeczny O, Sherbinin A de, Simlinger F, Sitati A, Sultana S, Young HR, van der Geest K, van den Homberg M, Wallimann-Helmer I, Warner K, Zommers Z (2019) Science for Loss and Damage. Findings and Propositions. In: Mechler R, Bouwer LM, Schinko T, Surminski S, Linnerooth-Bayer J (eds) Loss and Damage from Climate Change. Springer International Publishing, Cham, pp 3–37

Mechler R, Deubelli TM (2021) Finance for Loss and Damage: a comprehensive risk analytical approach. Current Opinion in Environmental Sustainability 50:185–196. doi: 10.1016/j.cosust.2021.03.012

Navrud S, Vondolia GK (2020) Farmers' preferences for reductions in flood risk under monetary and non-monetary payment modes. Water Resources and Economics 30:100151. doi: 10.1016/j.wre.2019.100151

Ndehedehe CE, Usman M, Okwuashi O, Ferreira VG (2022) Modelling impacts of climate change on coastal West African rainfall. Model. Earth Syst. Environ. 8:3325–3340. doi: 10.1007/s40808-021-01302-5

Ntajal J, Lamptey BL, Mahamadou IB, Nyarko BK (2017) Flood disaster risk mapping in the Lower Mono River Basin in Togo, West Africa. International Journal of Disaster Risk Reduction 23:93–103. doi: 10.1016/j.ijdrr.2017.03.015

Nur L, Simonet C, Caravani A (2017) Disaster risk insurance and the triple dividend of resilience. Working Paper, London, United Kingdom
Odemerho FO (2015) Building climate change resilience through bottom-up adaptation to flood risk in Warri, Nigeria. Environment and Urbanization 27:139–160. doi: 10.1177/0956247814558194
Oduniyi OS, Antwi MA, Tekana SS (2020) Farmers' Willingness to Pay for Index-Based Livestock Insurance in the North West of South Africa. Climate 8:47. doi: 10.3390/cli8030047
Olokesusi F, Olorunfemi FB, Onwuemele A, Oke MO (2015) Awareness of and Responses to the 2011 Flood Warnings Among Vulnerable Communities in Lagos, Nigeria. In: Werlen B (ed) Global sustainability, cultural perspectives and challenges for transdisciplinary integrated … research. Springer, [Place of publication not identified], pp 203–223
Onwuemele A (2018) Public Perception of Flood Risks and Disaster Preparedness in Lagos Megacity, Nigeria. Academic Journal of Interdisciplinary Studies 7:179–185. doi: 10.2478/ajis-2018-0068
Oulahen G (2015) Flood insurance in Canada: implications for flood management and residential vulnerability to flood hazards. Environ Manage 55:603–615. doi: 10.1007/s00267-014-0416-6
Oyedele P, Kola E, Olorunfemi F, Walz Y (2022) Understanding Flood Vulnerability in Local Communities of Kogi State, Nigeria, Using an Index-Based Approach. Water 14:2746. doi: 10.3390/w14172746
Oyekale AS, Oladele OI, Mukela F (2013) Impacts of flooding on coastal fishing folks and risk adaptation behaviours in Epe, Lagos State. Afr. J. Agric. Res. 8:3392–3405. doi: 10.5897/AJAR12.730
Parkoo EN, Thiam S, Adjonou K, Kokou K, Verleysdonk S, Adounkpe JG, Villamor GB (2022) Comparing Expert and Local Community Perspectives on Flood Management in the Lower Mono River Catchment, Togo and Benin. Water 14:1536. doi: 10.3390/w14101536
Pill M (2022) Towards a funding mechanism for loss and damage from climate change impacts. Climate Risk Management 35:100391. doi: 10.1016/j.crm.2021.100391
Rameshwaran P, Bell VA, Davies HN, Kay AL (2021) How might climate change affect river flows across West Africa? Climatic Change 169. doi: 10.1007/s10584-021-03256-0
Reynaud A, Nguyen M-H, Aubert C (2018) Is there a demand for flood insurance in Vietnam? Results from a choice experiment. Environ Econ Policy Stud 20:593–617. doi: 10.1007/s10018-017-0207-4
Salami RO, Meding JK von, Giggins H (2017) Vulnerability of human settlements to flood risk in the core area of Ibadan metropolis, Nigeria. Jamba 9:371. doi: 10.4102/jamba.v9i1.371
Schaefer L, Waters E, Kreft S, Zissener M (2016) Making Climate Risk Insurance Work for the Most Vulnerable: Seven Guiding Principles. UNU-EHS Publication Series, Policy Report, Bonn
Schäfer L, Warner K, Kreft S (2019) Exploring and Managing Adaptation Frontiers with Climate Risk Insurance. In: Mechler R, Bouwer LM, Schinko T, Surminski S, Linnerooth-Bayer J (eds) Loss and Damage from Climate Change. Springer International Publishing, Cham, pp 317–341
Schendel T, Thongwichian R (2017) Considering historical flood events in flood frequency analysis: Is it worth the effort? Advances in Water Resources 105:144–153. doi: 10.1016/j.advwatres.2017.05.002
Schinko T, Mechler R, Hochrainer-Stigler S (2019) The Risk and Policy Space for Loss and Damage: Integrating Notions of Distributive and Compensatory Justice with Comprehensive Climate Risk Management. In: Mechler R, Bouwer LM, Schinko T, Surminski S, Linnerooth-Bayer J (eds) Loss and Damage from Climate Change. Springer International Publishing, Cham, pp 83–110
Schlef KE, Kaboré L, Karambiri H, Yang YE, Brown CM (2018) Relating perceptions of flood risk and coping ability to mitigation behavior in West Africa: Case study of Burkina Faso. Environmental Science & Policy 89:254–265. doi: 10.1016/j.envsci.2018.07.013
Seifert I, Botzen WJW, Kreibich H, Aerts JCJH (2013) Influence of flood risk characteristics on flood insurance demand: a comparison between Germany and the Netherlands. Nat. Hazards Earth Syst. Sci. 13:1691–1705. doi: 10.5194/nhess-13-1691-2013
Seifert-Dähnn I (2018) Insurance engagement in flood risk reduction – examples from household and business insurance in developed countries. Nat. Hazards Earth Syst. Sci. 18:2409–2429. doi: 10.5194/nhess-18-2409-2018
Serra-Llobet A, Tourment R, Montané A, Buffin-Belanger T (2022) Managing residual flood risk behind levees: Comparing USA , France, and Quebec (Canada). J Flood Risk Management 15. doi: 10.1111/jfr3.12785
Surminski S, Eldridge J (2017) Flood insurance in England - an assessment of the current and newly proposed insurance scheme in the context of rising flood risk. J Flood Risk Management 10:415–435. doi: 10.1111/jfr3.12127
Surminski S, Oramas-Dorta D (2014) Flood insurance schemes and climate adaptation in developing countries. International Journal of Disaster Risk Reduction 7:154–164. doi: 10.1016/j.ijdrr.2013.10.005
UNDP (2021) UNDP launches new Insurance and Risk Finance Facility. https://www.undp.org/press-releases/undp-launches-new-insurance-and-risk-finance-facility. Accessed 13 Oct 2023
UNDRR (2023a) Residual Risk. https://www.undrr.org/terminology/residual-risk. Accessed 27 Aug 2023
UNDRR (2023b) Risk Transfer. https://www.undrr.org/terminology/risk-transfer. Accessed 01 Sep 2023

United Nations (2010) Flood in Togo | UN-SPIDER Knowledge Portal. https://un-spider.org/advisory-support/emergency-support/3829/flood-togo. Accessed 11/30/2022

United Nations (2015) Sendai Framework for Disaster Risk Reduction 2015-2030

Warner K, Kreft S, Zissener M, Hoeppe P, Bals C, Loster T, Linneroth-Bayer J, Tschudi S, Gurenko E, Haas A, Young S, Kovacs P, Dlugolecki A, Oxley A (2012) Insurance solutions in the context of climate change-related loss and damage: Needs, gaps, and roles of the Convention in addressing loss and damage: Munich Climate Insurance Initiative (MCII) submission to the SBI Work Programme on Loss and Damage. Policy Brief, Bonn

World Bank (n.d.) Disaster Risk Financing and Insurance (DRFI) Program. https://www.worldbank.org/en/programs/disaster-risk-financing-and-insurance-program. Accessed 13 Oct 2023

World Food Programme (2022) West Africa hard-hit by climate crisis as deadly floods decimate lives and livelihoods | World Food Programme. https://www.wfp.org/news/west-africa-hard-hit-climate-crisis-deadly-floods-decimate-lives-and-livelihoods. Accessed 11/30/2022

Yankson PWK, Owusu AB, Owusu G, Boakye-Danquah J, Tetteh JD (2017) Assessment of coastal communities' vulnerability to floods using indicator-based approach: a case study of Greater Accra Metropolitan Area, Ghana. Nat Hazards 89:661–689. doi: 10.1007/s11069-017-2985-1

Yiwo E, Jato-Espino D, Carracedo P, Brito MM de (2022) Multi-stakeholder perception on flood management in Ghana: Analysis of drivers and potential solutions, with a focus on surface permeability. International Journal of Disaster Risk Reduction 76:102990. doi: 10.1016/j.ijdrr.2022.102990

2. When does risk become residual? - A systematic review of research on flood risk management in West Africa (First academic journal publication)

Published originally as: Wagner, S., Souvignet, M., Walz, Y, Balogun, K., Komi, K., Kreft, S., and Rhyner, J.: When does risk become residual? A systematic review of research on flood risk management in West Africa. Regional Environmental Change 21, 84 (2021). https://doi.org/10.1007/s10113-021-01826-7

Abstract

Flood events in West Africa have devastating impacts on the lives of people. Additionally, developments such as climate change, settlement expansion into flood-prone areas, and modification of rivers are expected to increase flood risk in the future. Policy documents have issued calls for conducting local risk assessments and understanding disaster risk in diverse aspects, leading to an increase in such research. Similarly, in a shift from flood protection to flood risk management, the consideration of various dimensions of flood risk, the necessity of addressing flood risk through an integrated strategy containing structural and non-structural measures, and the presence of residual risk are critical perspectives raised. However, the notion of "residual risk" remains yet to be taken up in flood risk management-related academic literature. This systematic review seeks to approach the notion of residual risk by reviewing information on flood impacts, common measures and recommendations in academic literature. The review reveals various dimensions of impacts from residual flood risk aside from material damage, in particular, health impacts and economic losses. Infrastructural measures were a dominant category of measures before and after flood events and in recommendations, despite their shortcomings. Also, spatial planning interventions, a more participatory and inclusive governance approach, including local knowledge, sensitisation, and early warning systems were deemed critical. In the absence of widespread access to insurance schemes, support from social networks after flood events emerged as the most frequent measure. This finding calls for in-depth assessments of those networks and research on potential complementary formal risk transfer mechanisms.

Keywords: flood, residual risk, risk management, West Africa, systematic review

2.1 Introduction

Flood events in West Africa have inflicted devastating impacts on the lives of its inhabitants (Badou et al. 2019). Region-wide flood events, such as in 2007 (UN OCHA 2007), 2009 (UN OCHA 2009), 2010 (UN OCHA 2010), 2012 (UN OCHA 2012), 2016 (UN OCHA 2016), or most recently in 2020 (ERCC 2020), illustrate they are reoccurring more frequently, and with high severity in many places, causing large

scale loss and damage. The Emergency Events Database (EM-Dat), which records essential disaster data on a global scale, identifies 249 large-scale flood events (>10 fatalities or 100 affected people), which caused approximately 3,800 deaths and affecting about 25 million people from 1991 – 2019 in the Economic Community of West African States (ECOWAS) (EM-Dat 2020). ECOWAS member states include Benin, Burkina Faso, Ivory Coast, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Cape Verde, and Togo (ECOWAS 2020). Furthermore, despite uncertainties in several precipitation indices (Dosio et al. 2019), Global Climate Models (GCMs) and Regional Climate Models (RCMs) indicate shorter, more intense and later rainy seasons for West Africa due to climate change (Vizy and Cook 2012, Dunning and Black 2018, Dosio et al. 2019). This trend is expected to lead to an increase in harmful flood and drought events in the region (Akinsanola and Zhou 2019). Moreover, human activity, such as dam construction, alters natural river regimes (Mahe et al. 2013), whilst intensive urban expansion is projected to continue in flood exposed areas such as the Niger river and low-elevation coastal zones (LECZ) along the Gulf of Guinea up to 2030 (Güneralp et al. 2015).

In research as well as policy-making, there has been a growing awareness for the need to shift from a flood protection paradigm to flood risk management (FRM) (Hartmann and Albrecht 2014, Evers et al. 2016, Thomas and Knüppe 2016, Roos et al. 2017). While in the conventional flood protection paradigm, floods are usually addressed in a top-down manner by centrally implemented structural measures; an FRM approach calls for an integrated and synergetic combination of structural and non-structural measures implemented by various actors in a polycentral and participatory manner (Grabs et al. 2007, WMO 2009, Sayers et al. 2013, Challies et al. 2016, Milman et al. 2018). Contrary to conventional flood protection approaches, FRM also led to the perspective that flood risk can seldomly be reduced entirely, thus requiring strategies to address the residual risk that remains unaddressed despite risk-reducing measures being in place or their potential failure (Plate 2002, Ludy and Kondolf 2012, Arrighi et al. 2018). Similarly, according to current perspectives in the field of Disaster Risk Reduction (DRR), residual risk is termed as “the disaster risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained” (UNDRR 2020a, online). Therefore, “the presence of residual risk implies a continuing need to develop and support effective capacities for emergency services, preparedness, response and recovery, together with socioeconomic policies such as safety nets and risk transfer mechanisms, as part of a holistic approach” (UNDRR 2020a, online).

In addition, FRM seeks an expansion of risk dimensions to encompass not only the possibility of material damage but also health impacts, economic damages, the destruction of cultural heritage or impaired livelihood opportunities, and ensuing poverty (EU 2007, WMO 2009). The need for a broader

and more thorough understanding of disaster risk as a basis for achieving DRR has also been underscored in the realm of policy. For example, in 1989 the United Nations proclaimed the decade of 1990-2000 as the "International Decade for Natural Disaster Reduction" to enhance international cooperation on the topic (UN 1989). Moreover, the Hyogo Framework for Action 2005-2015 (HFA) already called for local risk assessments and to effectively integrate disaster risk considerations into policies, planning, and programming (UN 2005). Also, with its first priority, the ensuing Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) emphasises the importance of understanding disaster risk in all its dimensions (such as vulnerability, capacity, exposure, and hazard) as well as their interconnected impacts to inform disaster risk management meaningfully (UN 2015). Those developments have led to an increased number of publications discussing local flood impacts and efforts of FRM within the academic literature, also for the West African region. However, those publications are mainly case studies and thus primarily provide context-specific information on a local level.

Previous review studies on academic literature relating to FRM in West Africa have not yet summarised works for the entire region with a systematic review approach. On the regional scale, work focussing on such literature includes a review of gaps and challenges of FRM that has been carried out in four selected coastal West African cities (Ouikotan et al. 2017). However, besides considering a limited number of coastal cities, it did not apply a systematic review approach. Similarly, Badou et al. (2019) have carried out a literature review that summarised flood statistics, triggers of floods, solutions for prevention and mitigation of flood effects as mentioned by research, and future research priorities. Even though it is based on academic case studies, it does not offer a systematic approach to the research synthesis. Moreover, FRM-related review studies in the West African region have often focussed on one country or city. Also, they are either occupied with Nigeria or Ghana. On the one hand, for Nigeria, there are reviews on the impact of floods on Nigeria's achievement of the sustainable development goals (Echendu 2020), on sustainable FRM-practices in flood-prone areas of Nigeria (Cirella and Iyalomhe 2018), on the challenges and opportunities of FRM in Nigeria (Oladokun and Proverbs 2016), on the National Disaster Management Framework of Nigeria (Olanrewaju et al. 2019). For the city of Lagos in Nigeria, review papers examined the FRM practices of public and private actors (Adelekan 2016) and factors relating to the flood hazard, exposure and vulnerability, and challenges to reducing them (Nkwunonwo et al. 2016). On the other hand, for Ghana, there are reviews on current flood risk management practices as well as gaps and opportunities for improving resilience (Almoradie et al. 2020) and on emerging trends in FRM in the country (Ahadzie and Proverbs 2011). Of those reviews, only a few followed a systematic review approach. Furthermore, none of them explicitly considered the aspect of residual risk and how its resulting impacts are addressed.

Therefore, applying such a review approach to all West African countries will enable a broader discussion of trends in FRM at the regional level.

The aim of this review is to better understand the role of residual risk in FRM-related research for the region of West Africa. To achieve this, the article provides a systematic review of academic literature (journal articles and book chapters) and the contextual information it provides for FRM-related aspects in the region of West Africa. The analytical approach of this paper and its research questions to collect data on FRM measures and residual risk is summarised in Figure 2.1, drawing upon the perspectives of FRM and DRR mentioned above. This review's approach is to use the onset of the most recent flood event contained within the case study as a point of reference, to determine whether risk remained unmanaged or not. Thus, this review first analyses those FRM measures that have been applied before the onset of the most recent flood event, as reported in the case study. Second, the analysis focusses on the observed flood impacts as evidence-based indications of residual flood risk that materialised despite previous risk-reducing measures being implemented. Third, measures that have been applied after the onset of the most recent flood event to deal with the impacts of residual flood risk are analysed. Finally, recommendations produced as part of research to further address residual flood risk will be summarised in this review.

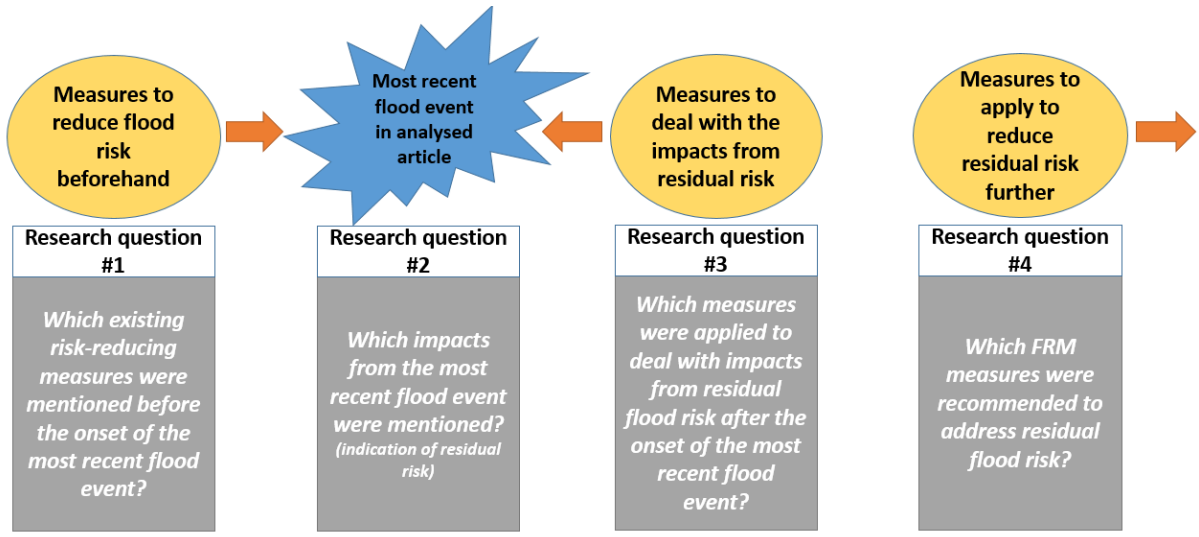


Figure 2.1 Analytical approach of the review paper and visualization of research questions

2.2 Method

In environmental sciences, systematic reviews are increasingly carried out in research relating to climate change adaptation (Berrang-Ford et al. 2011, Ford et al. 2014, Lesnikowski et al. 2015, Ford et al. 2016, Epule et al. 2017, Biesbroek et al. 2018, Shaffril et al. 2018, Owen 2020), drought risk (Kamara et al. 2018, Hagenlocher et al. 2019) and to FRM (Wellens et al. 2013, Abbas et al. 2016, Nordbeck et al. 2019, Carrick et al. 2019) due to their ability to provide a comprehensive summary of existing trends and foci in academic and/or grey literature. However, the variation in methodological approaches and the varying levels of transparency have been pointed out and were met with a set of proposed components by Berrang-Ford et al. (2015) for the standardisation of such research concerning the research questions/aim, data source, and document selection, and analysis and presentation of results. This study is seeking to address each of those aspects as a guide for enhanced transparency in this review paper. Furthermore, the article draws upon guidance from Siddaway et al. (2019) and Mengist et al. (2020) on the procedure of carrying out this systematic review, which is outlined in the section. Also, the article illustrates the review process in the form of a flow chart (Figure 2.2) as recommended by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, which formulates a minimum set of items for reporting the review procedure (Page et al. 2021).

Documents that were written in either English or French were searched for using sets of relevant English and French search terms (Annex 1). The keywords were selected in those languages since they are the most prevalent official languages in the ECOWAS region (with the exception of Guinea-Bissau and Cape Verde). Research areas in selected documents were mapped to illustrate a potential reporting bias in the geographical representation of West African countries in the final data set. Research published from 1991 onward up to 2019 was selected because the earliest large scale flood event within the UN's "International Decade for Natural Disaster Reduction" (1990-2000) in ECOWAS states listed on the EM-Dat database occurred in 1991 (EM-Dat 2020). The final set of search terms was selected in an iterative process by seeking additional keywords identified in relevant articles that were in previously identified documents. The saturation point was deemed to be reached when several newly added search terms were only adding a small single-digit number to the number of articles obtained by the query. The final set of terms was searched on 29th July 2020.

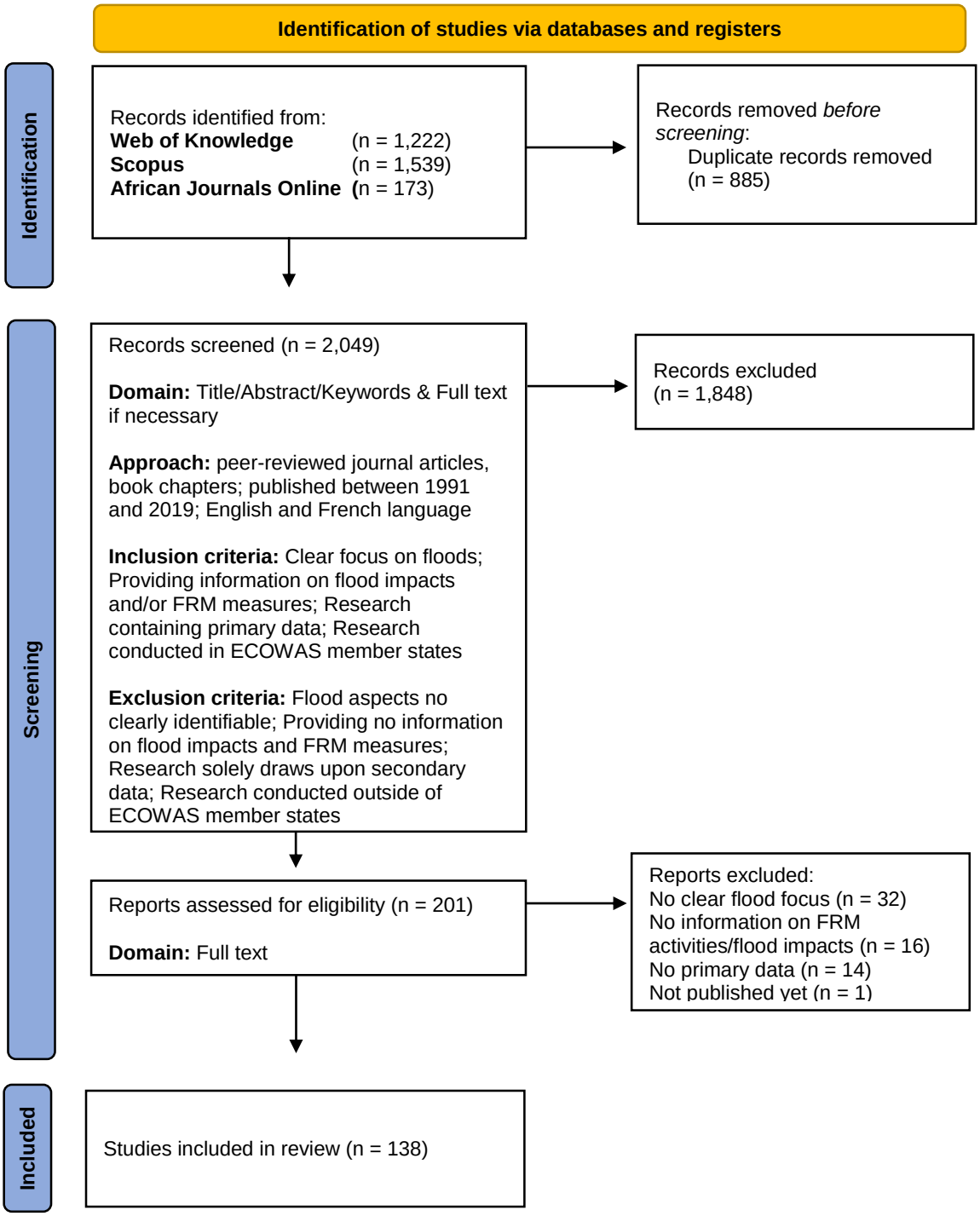


Figure 2.2 Flow chart of review procedure

(adapted from Page et al. 2021)

As outlined in Figure 2.2, relevant literature was searched for in Web of Knowledge and Scopus because they are the most extensive databases for peer-reviewed research. Additionally, African Journals Online (AJOL) was included as a database because it contained additional relevant research

from local research institutions that mainly were not listed in the other two databases. However, the authors are aware that additional relevant research might be published in other databases as those considered for this review. After the initial search yielded 2,934 documents, 885 duplicates were removed, which resulted in a list of 2,049 unique documents. Original research articles, in the form of peer-reviewed articles and book chapters containing primary data from field-based research, were selected as document types for this review. The explicit explanation of the primary data collection process was taken as a quality criterion for the inclusion of a document into the review.

The retrieved documents were screened in three rounds of review. The first round of screening was done by the primary author, who assessed the title, abstract, and keywords of each article, indicating their relevance by stating “yes”, “no”, or “perhaps”. Similarly, in the second round of screening, the entire list of articles was assessed independently by a team of eight reviewers to minimise personal selection bias, of which each member received a share of the entire set of articles. The team of reviewers then also indicated the relevance of each article by stating “yes”, “no”, or “perhaps”, without seeing the results of the first round of screening. The purpose of the third review round was to arbitrate judgments in case the first and the second rounds of review differed in their judgment, or if both parties submitted “perhaps”. The final reviewer indicated “yes” or “no” to make the final judgment based on the title, abstract keywords, and the full article if necessary. All reviewers assessed the relevance of articles based on the same inclusion and exclusion criteria (Figure 2.2). Documents were included if they unambiguously focussed on floods but excluded if they combined information about flood impacts or FRM measures with other hazards or with climate change in an inseparable way. Also, studies were excluded that focussed merely on assessing the physical flood hazard but provided no information on the research questions. Contrarily, those that contained information on impacts and responses (flood impacts from FRM measures before and after the most recent flood event or recommended measures to reduce residual flood risk further) were included. Finally, only research that contained primary data, and that was carried out in the selected West African countries of interest was included. Selected West African countries are the member states of ECOWAS, namely Benin, Togo, Senegal, The Gambia, Guinea, Guinea-Bissau, Mali, Ivory Coast, Sierra Leone, Burkina Faso, Niger, Nigeria, Ghana, Liberia, and Cape Verde. Research that was purely based on secondary data or carried out outside of the countries of interest was excluded.

The process of screening by the reviewers led to a selection of 201 documents, which were read in their entirety to decide about their eligibility. The coding of information relating to the research questions was done by three reviewers, including the main author, using the software MAXQDA. The reviewer team chose the software because of being able to easily exchange and merge project documents and its easy-to-operate user interface for coding text (VERBI 2021). Also, Excel sheets

summarising each code can be exported and used to visualise and analyse the data as done for this review. To minimise bias in coding articles and deciding on their eligibility, the main author and the two other reviewers went through all 201 documents twice. If an impact or measure was mentioned to occur, or to be carried out, in a document, it was captured through open coding in MAXQDA. In this process, categories for impacts and measures emerged through continuously grouping and regrouping the results (Table 2.1). The information on impacts and measures are summarized by using descriptive statistics in this review. In addition, the working definitions for the categories of impacts and measures, as well as a comprehensive overview of the composition of each category of measures, can be found in Annex 8, 9, 10 and 11. Coded measures and impacts are counted once per document if they appear in the case study. This approach was chosen because the main research aim is to showcase the range of the composition of applied or recommended measures in FRM and the dimension of impacts in the case studies. It should also be made clear that one single document can have research areas in multiple countries. By reading the documents in their entireity during the coding process, 138 were finally included (Annex 2) and considered to be relevant for this review, also based on whether each document met the inclusion and exclusion criteria while being read in full-length (Figure 2.2). In this process, 32 documents were excluded for not focussing on floods clearly enough, 16 for not providing enough information on FRM measures or flood impacts, 14 for not containing primary data and 1 for not being published yet.

Table 2.1 List of indicators guiding data collection

Indicator	Categories	Sub-categories
Country	Nigeria, Ghana, Senegal, Benin, Niger, Burkina Faso, Togo, Ivory Coast, Cape Verde, The Gambia, Sierra Leone, Mali, Guinea-Bissau, Liberia, Guinea	
Geographical area	Urban, Coastal zone, Rural, Peri-urban, Delta region	
Types of floods	Pluvial flood, Fluvial flood, Coastal flood, Groundwater flood	
Methods used for data collection	Surveys, Qualitative interviews (semi-structured, in-depth, key informant), Field observations, Focus groups, Photography/Photo elicitation, Workshops, Stakeholder meetings, Transect walks, Collective mapping	
FRM measures (before and after the onset of the most recent flood event & recommended)	Infrastructural	Drainage construction, Flood defense structures, Elevation of buildings or infrastructure, Dams/dikes, Land filling (Sand, stone, waste, etc.), Dredging river channels/channelisation, Riverbank reinforcement/embankments, Water storage ponds/reserviors, Building/using walkways, Reinforcing or constructing strong buildings, Use of sand bags for flood breaks, Water pumping machines, Demi-lunes, Draining water bodies, Canoes, Expansion/construction of sanitation network, Gabions, Permeable pavements, Reinforcing infrastructure, Construction of basic infrastructure, Hillslopes, Pumps, Stone bonding, Ridges across slopes, Digging of boreholes, Using generators, Mud heaps, Building bridges, Watertight trenches, Breakwater systems, Closure of dam, Land reclamation

	Mutual support	Support from community/social environment, Social relations, Formation of associations and groups, Advocating for disadvantaged groups, Volunteer groups
	Maintenance activities	Clearing drainage, Waste management, Maintaining existing flood drainage infrastructure, Clean-up activity, Reconstruction and rehabilitation, Repair activity, Removing water out of flooded area, Better waste management, Procuring lost items, Better waste management behaviour, Improved sanitation, Ensuring continuation of household activity, Update flood control measures, Maintenance of existing flood defense systems, Recover lost livestock
	Awareness-raising, training & education	Civic sensitization to flood risk, Warning campaigns in media, Raising awareness to improve waste management behaviour, Capacity-building of staff, Provision of alternative skill development, Women empowerment program, Teaching of coping and adaptation skills, Public health education, Enhancing education, Raising awareness on the need of obtaining building permits, Increase volunteer particpation, Health inspectors
	Information resources	Early warning systems, Weather information/forecasts, Establishment of a Geographic Information System (GIS), Looking for flood information on the news/social media, Radio/TV/Phone ownership, Collaborate for media coverage of the event, Reliance on extension information, Better warning/risk communication, Forecasting, Accessibility of weather and environmental information, Seeking access to information sources, Credible sources of information
	(Preparing/providing) assistance & response	Raising response capacities/relief activities, Governmental assistance, Assistance from NGOs/relief organisations, Establishment of emergency/contingency plans, Risk management committees, Storing food, Coordination of disaster responses, Formal loans, Drills, Preparing for power cuts, Keping medical kit in the household, Provision of relief items, Provision of shelters, Assistance from community-based organizations, Assistance from religious institutions, Assistance from private companies, Creation of employment, Emergency preparedness mechanisms, Coordination of flood response, Acquiring pumps for houses, Personal preparations, Credit access, Encouraging risk management at the village/community level, Emergency drills, Creation of an emergency response agency, Transportation in case of emergency, Preparing for power cuts, Creating safe zones, Extend governmental response from urban to rural areas
	Relocation	Permanent relocation, Temporary relocation, Forced eviction and resettlement from flood areas, Moving items/animals to a safe place, Farming in higher areas, Avoid farming in exposed zones, Migration
	Spatial planning interventions	Formalization of informal settlements, Restructuration of areas, Creation of social housing, Participative planning, Flood-related land use planning, Enforcement of land use laws/demolition, Monitoring implementation of flood-reducing infrastructure, More

		integrated land use planning, Urban upgrading programs, Incentives for people to move out of flood zones, Environmental management, Better building codes, Provision of sanitation, Investing in other areas apart from the capital
	Use of local knowledge and skills	Local knowledge of floods, Sharing technical knowledge, Employing more qualified staff, Staying alert, Appreciation of local/traditional knowledge in disaster risk management (DRM), Organization and leadership
	Policies	Better integration of groups at risk, Active collaboration among stakeholders, Policies which alter the resources of people at risk, Assignment of clear responsibilities, Law and policy enforcement, Adjusting policies to local context, Formalisation of exchange between actors, Decentralisation of agencies/DRR capacities, More funds for DRR, Environmental management policies, Public policies to reduce flood risk, Creation of development/response agencies, Provision of funds for DRR, Tolerance/formalization of informal settlements, Decentralisation of agencies, Sanitation laws, Transfer of responsibilities to lower level government bodies, Institutional reforms, Cooperation with private entities, Enhancing institutional capacity, International cooperation, Long-term orientation of policies, Audit on corruption prevention
	Insurance	Obtaining insurance cover, Receiving compensation from insurance
	Nature-based solutions	Wetland conservation, Afforestation, Mangroves, Agroforestry, Urban greening, Use of flood plains to retain water, Greening of lands, Consume wild fruits and plants, Protecting and using natural barriers, Burning of fruit peels to drive away mosquitoes, Rehabilitating/protecting wetlands, Natural reserves in high risk areas, Green and hybrid measures, Reducing environmental degradation
	Research & assessment	Research on potential risk-reducing measures, Consider social aspects of flood risk, Mapping of flood zones, Hydrological data collection, Risk assessments/mapping, Hazard modelling, Institutional assessments, Flood risk research, Humanitarian/Situation assessment, Research on causal interaction in disaster risk, Establishing research cooperations, Participatory research, Data collection on impact measurements, Collect population data, More research, Monitoring urban expansion
	Modification of practices	Modified agricultural techniques, Change of water supply practices, Switching off gas and electricity, Avoiding movement, Consuming less meals, Using rain boots, Supervising children, Dependence on market for food, Conflict resolution, Hire security guard, Modified washing behaviour, Trying to retrieve the rent, Living in one room only, Water harvesting, Practice intense fishing system, Sharing of family responsibilties between women and men, Switching off gas & electricty, Product pooling of produce
	Risk retention/ Using retained resources	Staying in flooded house/area, Saving/Use of savings, Inactivity, Consume stored food, Emergency funds

	Modification of livelihood	Non-agricultural activities, Diversification of economic activities, Fishing, Market gardening, Additional employment, Buy livestock, Selling goods/assets, Mutual exchanges/trade, Creation of income generating activities, Renting out exposed house, Encourage artisanal jobs, Encourage seed exchanges, Selling/renting new land titles
	Religious & Spiritual activities	Religious beliefs, Prayers/ fasting, Spiritual support, Religious support with social safety nets
	Health care	Provision of (affordable) health care, Self medication, Use of insect sprays/mosquito nets, Medication, Application of traditional medicine, Develop better health centres, Sanitizing flood water, Visiting midwives, Sanitation Following hygiene rules, Water treatment, Psychological support
Impacts from residual flood risks from the most recent flood event	Material damage	Damaged/destroyed buildings, Damaged possessions/goods, Damage to infrastructure, Crop damage, Loss of livestock, Damage of public facilities, Destruction of processed goods/produce, Damage to farms, Reduction of fish catch
	Health	Fatalities, Sickness and spread of diseases, Fear/mental health problems, Injuries, General status of poor health, Malnutrition, No immediate health care, Miscarriages
	Economic losses	Disruption of livelihoods/Income loss, Financial damages, Poverty and uncertainty
	Environmental degradation	Damaged farming land/land degradation, Polluted environment, Loss/disturbance of ecosystems
	Displacement & Homelessness	Displacement, Homelessness
	Lack of food/drinking water	Lack of drinking water/ water contamination, Lack of food/scarcity
	Lack of mobility	Disruption of general movement, Traffic interruption
	Interruption of social activities	Interruption of education, Negative impacts on social life, Crime/theft/violence/conflicts

2.3 Results

2.3.1 Meta-information

The review analysis showed that the number of FRM-related articles has steadily increased from 2011 onward (Annex 3) and that the majority of selected articles mentioned Nigeria and Ghana as research areas (Annex 4). Those countries are followed by Senegal, Benin, Niger, Burkina Faso, Togo, and Ivory Coast. Furthermore, Cape Verde, The Gambia, Sierra Leone, Mali, and Guinea-Bissau are countries that only featured once or twice in the selected articles. It is worth noting that the final set of selected articles did not represent Guinea and Liberia. Since most articles focussed on Nigeria and Ghana and urban or peri-urban areas (Annex 5), a bias towards those geographical areas must be considered in the results obtained. Furthermore, the geographic distribution of research areas was mapped (see Figure 2.3). The map illustrates that, according to the Köppen-Geiger classification from 1980-2016 (Beck et al. 2018), the research area spans nine different climatic zones, of which the following five cover the majority of this area: tropical, rainforest (Af); tropical, monsoon (Am); tropical, savannah (Aw); arid, desert, hot (BWh); and arid, steppe, hot (BSh). It became apparent that the eastern part of the region is widely covered by the selected research. In contrast, the western part is barely covered, with the exception of the Senegalese coast, The Gambia and singular studies in Cape Verde, Guinea-Bissau, and Sierra Leone. Flood types that were encountered in the review (Annex 6) were pluvial floods *(n = 93)*, fluvial floods *(n = 83)*, coastal floods *(n = 34)*, and groundwater floods *(n = 9)*. The variety of methods applied in case studies also translates into a varying understanding of concepts that relate to FRM such as risk, vulnerability, adaptation or coping. Methods for primary data collection (Annex 7) were surveys *(n = 97)*, qualitative interviews (semi-structured, in-depth, and key-informant) *(n = 73)*, focus groups *(n = 40)*, photography/photo-elicitation *(n = 13)*, workshops *(n = 11)*, stakeholder meetings *(n = 10)*, transect walks *(n = 6)*, and collective mapping *(n = 4)*. The following part of the section will summarise the information collected in the review process, based on the four research questions previously stated in chapter 1.

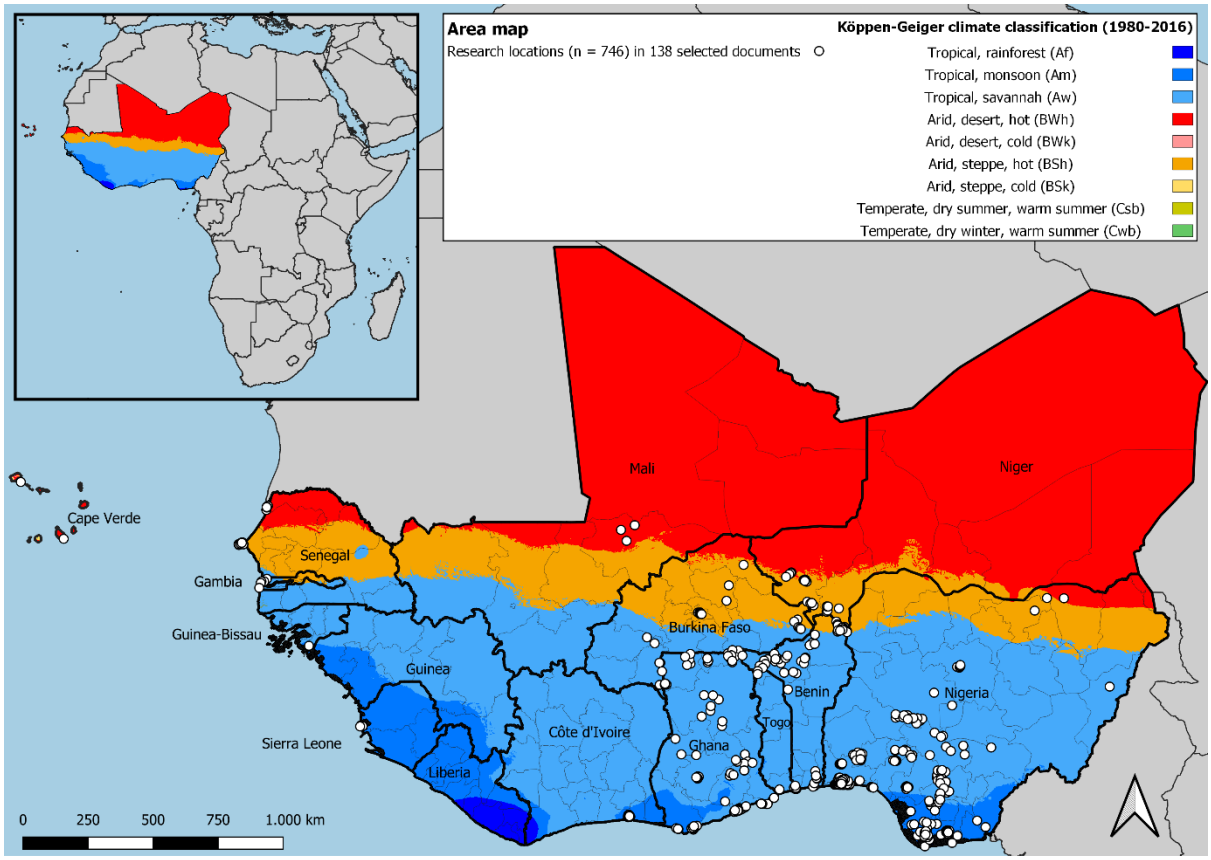


Figure 2.3 Geographical distribution of research locations in selected documents.

The authors excluded publications [73] and [81] (see Annex 3) from the map due to not specifying the research locations sufficiently. One article can contain several research areas, resulting in 746 research locations from 138 selected documents. Admin boundaries retrieved from (DIVA GIS 2020) and Köppen-Geiger climate classification data set from (Beck et al. 2018).

2.3.2 Which existing risk-reducing measures were mentioned before the onset of the most recent flood event?

The analysis shows that observed FRM measures that were mentioned before the most recent flood event (appearing in 109 out of 138 documents) most often fell into the category of infrastructural measures (Figure 2.4a), with drainage construction being the most outstanding among them (Figure 2.4b). Also, flood defense structures, elevating of buildings or infrastructure, landfilling, dams/dikes, and dredging of rivers/channelisation were mentioned as infrastructural measures. Following infrastructural measures, a cluster of six categories of risk management measures before the onset of the most recent flood event showed an equal prevalence. This comprises the following categories (Figure 2.4a) and measures (Figure 2.4b). Maintenance activities with measures such as clearing drainage infrastructure. Mutual support with measures such as material support from the community and social relations. Preparing/providing assistance & response with measures such as raising capacities for response and relief and the establishment of contingency plans. Awareness-raising, training and education with measures such as civic sensitisation to flood risk. Policies with measures

such as applying public policies to reduce flood risk and a flood control/development master plan. And finally, relocation with measures such as permanent relocation.

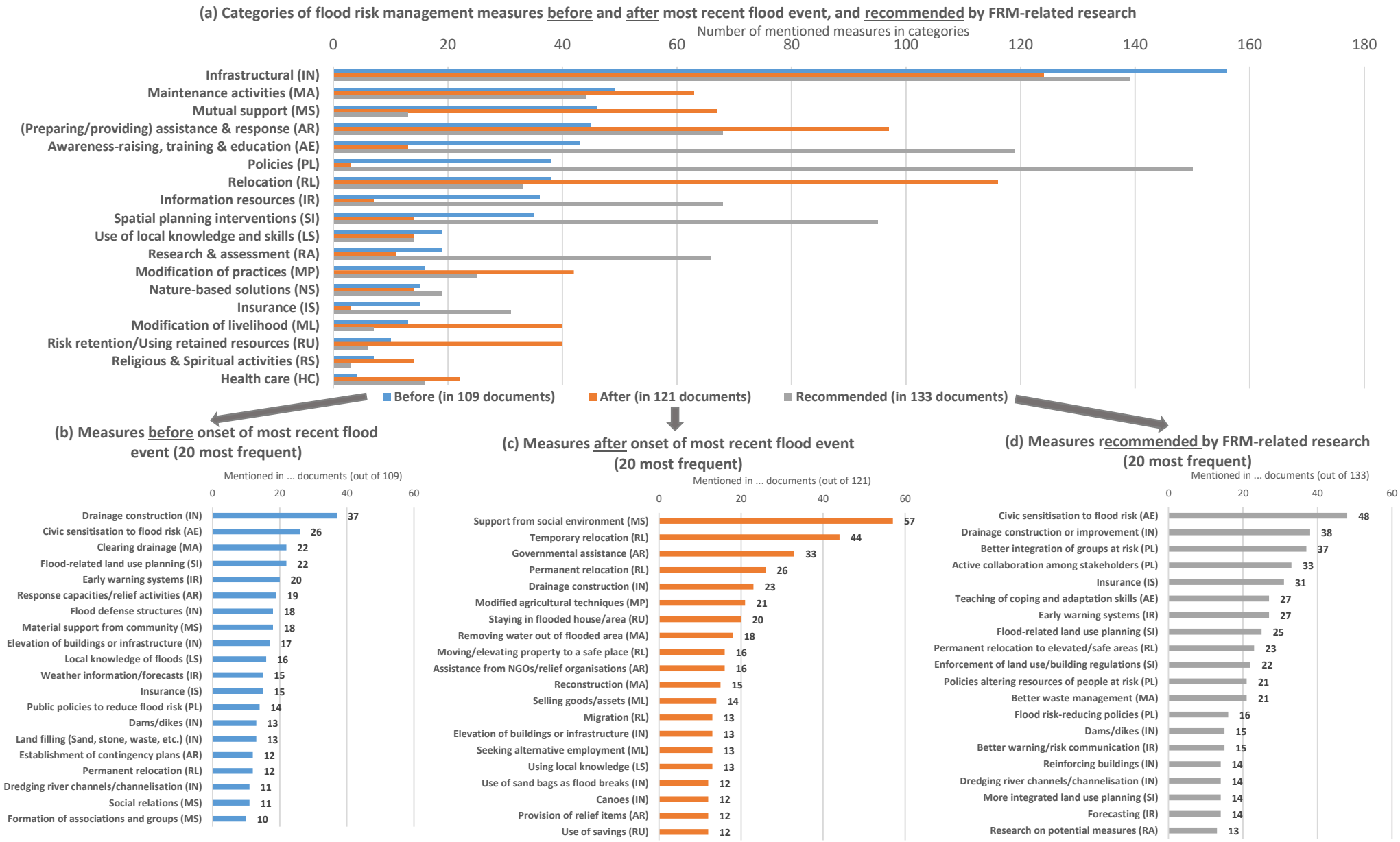


Figure 2.4 Overview of categories (a) and measures before (b) and after (c) the onset of the most recent flood event as well as (d) recommended measures by FRM-related research (one document can contain several categories and measures

2.3.3 Which impacts from the most recent flood event were mentioned in selected case studies?

Impacts from residual flood risk were analysed, which arose from the most recent flood event despite FRM measures or in their absence (appearing in 125 out of 138 documents). The results demonstrate that in the selected documents flood impacts most frequently fall into the category of material damage (Figure 2.5a) due to, for example, damaged buildings as the most outstanding impact, damaged possessions, damage to infrastructure, crop damage, loss of livestock and damage of public facilities (Figure 2.5b). However, health impacts *(n = 180)* also pose a significant risk resulting from a flood event in analysed case studies. They mostly materialize as fatalities, sickness and spreading of disease, as well as fear/mental health problems. Besides, economic losses *(n = 115)* are frequent impacts resulting from flood events in analyzed case studies. They often took the form of disruption of livelihoods/income loss, and financial damages. Additionally, environmental degradation *(n = 74)* played an important role in impacts which resulted from the most recent flood event in the selected documents. These impacts often resulted in damaged farming land/land degradation and a polluted environment. Finally, displacement and homelessness, lack of food/drinking water, interruption of social activities, and lack of mobility emerged as dimensions of flood impacts worth considering.

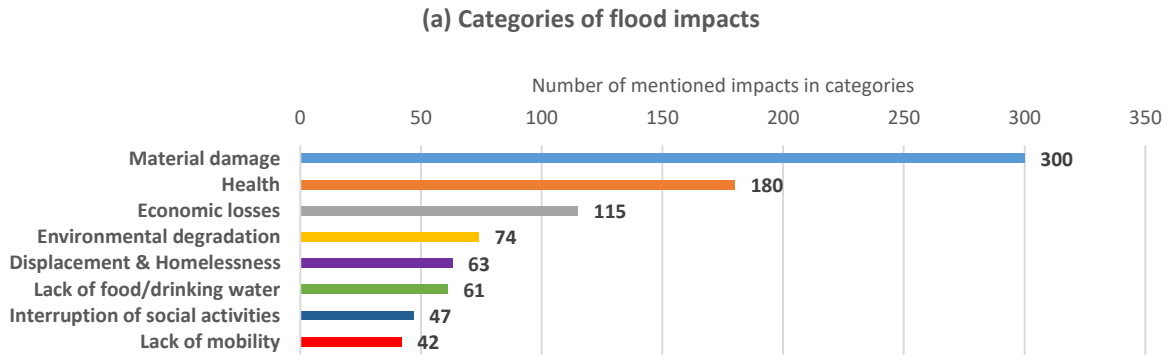
2.3.4 Which measures were applied to deal with impacts from residual flood risk after the onset of the most recent flood event?

The following paragraph summarizes measures that were applied to deal with impacts from residual flood risk after the onset of the most recent flood event (appearing in 121 out of 138 documents). Similarly, to before the onset of the most recent flood event, infrastructural measures were performed most frequently after its onset (Figure 2.4a). They often appeared as belated drainage/channel construction or by using sandbags as flood breaks (Figure 2.4c). Also, measures of relocation *(n = 116)* were performed very frequently after the most recent flood event had started. In comparison to before the onset of the flood event, they strongly increased after its onset. These measures unfolded as temporary relocation, permanent relocation, moving/elevating property to a safe place, and migration. Also, measures of mutual support played a highly important role after the onset of the most recent flood event *(n = 67)*. These measures were reported for example as receiving support from the social environment. It is worth noting that this measure was the most frequent after the onset of the most recent flood event. Despite being stated vaguely in many publications, some specified such mutual support activities as providing labour, mental, financial or material support, borrowing money and food or shelter to affected family members or friends. Moreover, reported measures focussing on providing/preparing assistance and a response played a crucial role after the onset of the flood

event *(n = 97)*. They were performed as governmental assistance, assistance from NGOs/relief organizations or in general as provision of relief items. Compensations received from insurance companies did not play a significant role.

2.3.5 Which FRM measures were recommended to address residual flood risk?

Finally, measures that were recommended in selected documents to address residual flood risk were identified in 133 out of 138 documents. In contrast to practiced measures before and after the onset of the flood event, measures to adjust policies *(n = 150)* were most frequently recommended by selected documents to deal with residual flood risk (Figure 2.4a). Such adjustments were recommended to better integrate groups at risk into decision-making, active collaboration among stakeholders, policies that alter the resources of people at risk, and policies which directly reduce flood risk (Figure 2.4d). Aside from being widely practiced before and after the onset of the most recent flood event, infrastructural measures were again highly recommended *(n = 139)* for further risk reduction efforts. Other recommended measures comprise, for example, of drainage construction or improvement, dams/dikes, reinforcing buildings, and dredging river channels/channelisation. Additionally, more effort towards measures aimed at awareness-raising, training and education *(n = 119)* were recommended by many selected documents. For example, those comprised of further efforts for civic sensitisation to flood risk and teaching of skills to cope with and adapt to floods. Interestingly, despite the fact that not many documents focussed on insurance explicitly in their assessments, it appears as the fifth-most frequently recommended measure.



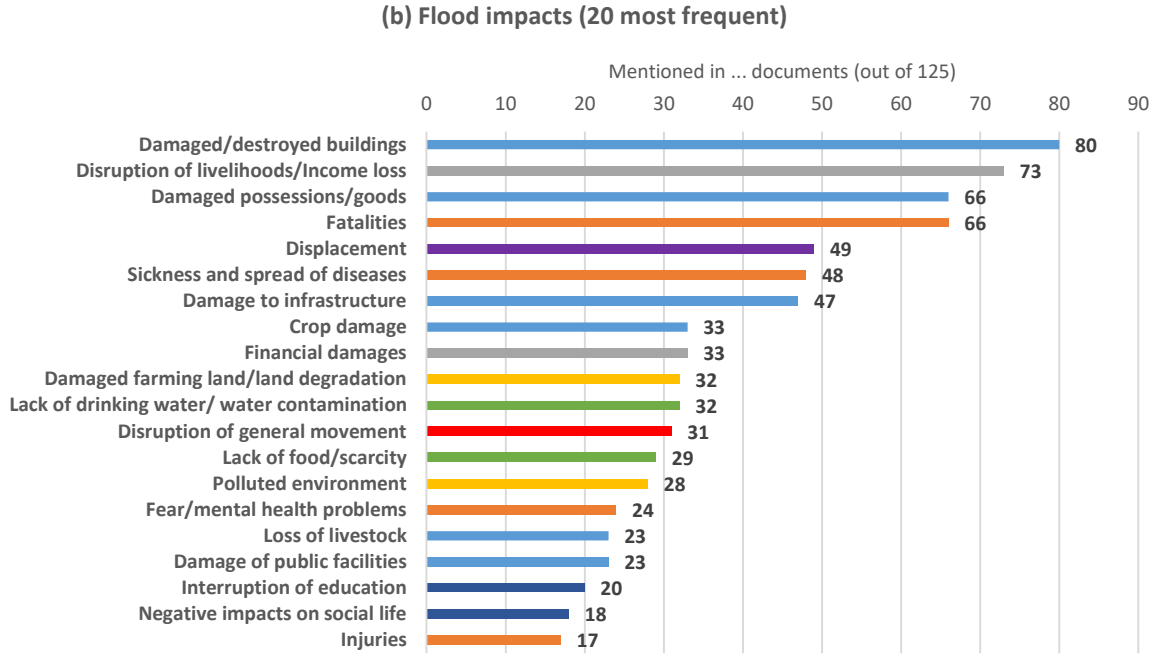


Figure 2.5 Categories of mentioned flood impacts from residual flood risks (a) and flood impacts (b) (one document can contain several categories and impacts)

2.4 Discussion

The academic literature analysed in this paper pinpoints the dimensions of impacts that resulted from residual flood risk for the West African region. They comprised most prominently material damage, health impacts and economic losses, but also environmental degradation, displacement and homelessness, lack of food/drinking water, interruption of social activities and lack of mobility. It is worth noting that the term “residual risk” was mentioned only once (Adelekan 2016) and not subject to direct analysis in any of the selected documents. Thus, the concept of residual risk has not yet been taken up in selected FRM-related literature. Material damage appeared to be a dominant category of impacts from residual flood risk (Figure 2.5a) in selected research according to the analytical approach of this review (Figure 2.1). Considering other types of impacts from residual flood risk identified by this review article more extensively will enrich the perspective of FRM. The most prevalent additional dimensions were health impacts and economic losses, which are also currently receiving increased attention due to being the most discussed impacts in the ongoing COVID-19 pandemic (Nicola et al. 2020, Holmes et al. 2020, El Zowalaty and Järhult 2020). This observation gains additional relevance regarding the low level of health care efforts to address flood impacts (Figure 2.4a) as well as the high activity to modify livelihoods after the onset of the most recent flood event identified in this review (e.g., Ajibade et al. 2013, Hetcheli 2013, Schaer 2015, Ajaero 2017, Oyerinde et al. 2017, Markantonis

et al. 2018, Atidegla et al. 2018, Afriyie et al. 2018; and Figure 2.4a). The political momentum in ECOWAS countries for addressing the health and economic impacts of the COVID-19 pandemic (IMF 2020) could help to pursue the possibility of joining efforts in reducing the risk of impacts from both floods and pandemics. In doing so, the consideration of fear and mental health problems arising from either traumatic flood experiences or pandemics should not be neglected. Also, the various dimensions of flood impacts resulting from residual risk underscore the need for research that assesses the causal chains of flood impacts and their mutual influence on each other.

Moreover, the review elaborated that infrastructural measures have been the most observed category of measures in the selected case studies (Figure 2.4a). The emphasis on infrastructural measures in FRM-related research is further underscored by a rare explicit application of nature-based solutions, as well as of recommendations for it (Figure 2.4a). The tendency for implementing infrastructural measures could be observed before (e.g., Campion and Venzke 2013, Odemerho 2015, Adelekan 2016, Kablan et al. 2019) and after (e.g., Mbow et al. 2008, Schaer and Hanonou 2017, Owusu Twum and Abubakari 2019, Bottazzi et al. 2019) the most recent flood event. Still, infrastructural measures were often recommended in FRM-related research (e.g., Saidu 2009, Adewole et al. 2015, Serpantié et al. 2019; and Figure 2.4a). The latter finding could point towards the inadequacies of existing systems, such as open drainage facilities blocked by waste (e.g., Lokonon 2016, Osayomi and Oladosu 2016, Danso and Addo 2017, Schlef et al. 2018) or having to resort to isolated efforts of flood defense structures on the house- or community-level, often in informal areas, with limited impact (Adelekan 2010, Schaer 2015, Bottazzi et al. 2018, Adekola et al. 2019). This was frequently mentioned in urban case studies. Also, the prevalence of recommendations for spatial planning interventions (Figure 2.4a) has to be understood in light of the limitations of infrastructural measures. Frequently mentioned measures were, for example, improved land use planning which better considers flood risk (e.g., Wahab and Falola 2017, Tiepolo et al. 2019) or the enforcement of existing land use plans to avoid the new construction of buildings of infrastructure in high risk areas (e.g., Onu et al. 2013, Ibitoye et al. 2019). However, it seems to remain a difficult task, regarding projections for urban expansion along the Niger river and low-elevation coastal zones (LECZ) along the Gulf of Guinea up to 2030 (Güneralp et al. 2015).

Regarding the polycentral and participatory approach of FRM, there appears to be a strong need for more participatory and inclusive governance to further reduce the impacts of residual flood risk further, given the strong recommendation by the selected documents for policy and law-related measures (Figure 2.4a). Those recommendations are often pointed towards better collaboration among stakeholders (e.g., Olokesusi et al. 2015, Ntajal et al. 2017, Young et al. 2019), better integrating groups at risk in relation to decision-making (e.g., Komi et al. 2016, Frick-Trzebitzky and

Bruns 2019) and altering their resources (e.g., Olanrewaju et al. 2019, Cirella et al. 2019). This need is also reflected in the current relative disregard of local knowledge and skills in dealing with floods (Figure 2.4a). Hence, future research projects should include a focus on how widely present and existing local knowledge and skills could be better integrated into decision-making processes in a meaningful way (e.g., Bonye and Godfred 2011, Biconne 2014, Ajibade and McBean 2014, Ngwese et al. 2018). It has also become apparent in this review that the documents identified civic sensitisation to flood risk as a priority action area for further efforts in flood risk reduction (e.g., Agbola et al. 2012, Adeleye and Ayangbile 2016, Ottah 2017, Abass et al. 2019; and Figure 2.4d). Such measures may include early warning systems, as they also appeared as a frequently recommended measure (e.g., Coker et al. 2014, Vissin et al. 2016, Egbinola et al. 2017; and Figure 2.4d). The need for this could be further enlarged by expected climatic changes for West Africa, which are projected to lead to shorter yet more intense rainy seasons (Vizy and Cook 2012, Dunning and Black 2018, Akinsanola and Zhou 2019, Dosio et al. 2019).

Remarkably, the most widely practised measure after the onset of a recent flood event was to seek support from the social environment (Figure 2.4c). While some documents did not define the measures more precisely (e.g., Boamah et al. 2015, Enete et al. 2016, Evadzi et al. 2018), others explicitly indicated them as providing labour, mental, financial or material support, borrowing money and food or shelter to affected family members or friends (e.g., Adelekan and Fregene 2015, Kielland 2016, Osman et al. 2016, Frick-Trzebitzky 2017, Ajaero et al. 2018). Thus, support from social networks can also aid in explaining the strong prevalence of temporary relocation after the onset of the flood events in case studies (Figure 2.4c). While indicating a high level of solidarity, the strong support within social networks also illustrates a lack of widespread access to or compensation by insurance schemes. More research could look into the types of risks shared in such social networks, their limitations, and which form of support aids in the recovery process. It is also worth exploring how efficient and effective those networks function in addressing residual flood risk, if the networks help alleviate inequality and if they are fair on their members. It could be of further interest if those social networks even take on the form of informal risk transfer arrangements, in which support is provided in exchange for social or financial benefits (UNDRR 2020). This aspect is particularly interesting since many documents recommended insurance for further residual flood risk reduction, despite only a few providing an explicit assessment of its suitability or usage (e.g., Oyekale et al. 2013, Antwi-Boasiako 2016, Osayomi and Oladosu 2016, Antwi-Boasiako 2017, Glago 2019). Thus, exploring if insurance can be helpful to address residual flood risk while considering the presence of existing informal arrangements appears highly relevant in this research context.

2.5 Conclusion

As floods in the West African region have become increasingly frequent and devastating in the past decades, it is essential to give an account of which FRM measures and impacts from residual flood risk are primarily addressed in academic literature. This review found residual risk and its management to be treated implicitly, if at all. An explicit focus is missing in the current FRM-related research carried out in West Africa and will deserve more attention in future. Also, the review identifies that FRM measures frequently comprise of infrastructural measures, maintenance activities, mutual support (in particular seeking support from the social environment), as well as the preparation/provision of assistance and response measures both before and after the most recent flood event mentioned in case studies. Among those, infrastructural measures emerged as dominant FRM component in this review. Besides, temporary and permanent relocation activities were frequently observed after the onset of the most recent flood event in selected documents. In addition, recommendations provided in selected documents to reduce residual flood risk were mainly categorised as adjustments of policies, infrastructural measures, awareness-raising, training and education, and spatial planning interventions.

Furthermore, certain limitations of the study should be observed. It was beyond the scope of the review to collect information on the effectiveness and efficiency of individual measures. Besides, additional relevant research might be published in other databases beyond those considered for this review (Web of Knowledge, Scopus, and African Journals Online). In addition, most analysed research was carried out in only a few countries (Nigeria and Ghana) and specific geographical areas (urban + peri-urban and coastal). This aspect affects the generalizability of the results for the entire West African region. Consequently, future research should consider other potentially flood-affected countries and areas that have as well remained neglected by existing research so far. Therefore, analyses could assess if the spatial distribution of FRM-related research reflects the spatial distribution of flood impacts in ECOWAS countries, by for example drawing upon data from the EM-Dat database. Finally, the varying understanding of concepts relating to FRM such as risk, vulnerability, adaptation or coping has to be observed when summarizing such information on a meta-level. However, it is beyond the scope of this review to compare and contrast those variations.

Future studies could either embark on more complex modeling that approaches residual flood risk by researching the synergies of FRM-measures, their limitations in reducing the risk of flooding and the various dimensions of impacts that arise from it. Or, as applied in this review, a focus on flood impacts that occur despite the implementation of FRM measures could also enrich case studies to approach residual flood risk from an empirical perspective. Moreover, more research on the role of social

networks in the recovery from flood impacts, the range of impacts they usually cover, and the conditions that prevail within them will be highly relevant. It will also be necessary to research if and to what extent financial damages are covered and if those arrangements qualify as risk transfer mechanisms. Such research will help devise locally appropriate mechanisms that help address floods impacts that put people in financial need. Those efforts should be coupled with more thorough and detailed assessments of the suitability of insurance in addressing residual flood risk, given its currently limited role. Besides, future research could acknowledge the strong prevalence of infrastructural measures by investigating the problems that appear in implementing adequate flood-reducing infrastructure more deeply and how to overcome them. In addition, it could be relevant to research to what extent such measures could be complemented or substituted by nature-based solutions, which currently do not play a role in FRM-related West African case studies yet. Furthermore, the body of selected literature strongly raised the need for more participatory approaches that ensure the involvement of the population at-risk in decision-making and research. Such efforts could be focussed on but not limited to spatial planning interventions, awareness-raising training and education, infrastructure construction. Finally, the use of local knowledge and skills in the form of FRM measures that the at-risk population already practices portrays another opportunity for such involvements. However, the latter aspect is not part of the dominant foci of practiced or recommended measures that this review identified but still should be subject to future research.

2.6. References

Abass K, Dumedah G, Frempong F (2019) Understanding the physical and human contexts of fluvial floods in rural Ghana. International Journal of River Basin Management:1–12. doi: 10.1080/15715124.2019.1653310

Abbas A, Amjath-Babu TS, Kächele H, Usman M, Müller K (2016) An overview of flood mitigation strategy and research support in South Asia: implications for sustainable flood risk management. International Journal of Sustainable Development & World Ecology 23:98–111. doi: 10.1080/13504509.2015.1111954

Adekola O, Lamond J, Adelekan I, Eze EB (2019) Evaluating flood adaptation governance in the city of Calabar, Nigeria. Climate and Development:1–14. doi: 10.1080/17565529.2019.1700771

Adelekan I, Fregene T (2015) Vulnerability of artisanal fishing communities to flood risks in coastal southwest Nigeria. Climate and Development 7:322–338. doi: 10.1080/17565529.2014.951011

Adelekan IO (2010) Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. Environment and Urbanization 22:433–450. doi: 10.1177/0956247810380141

Adelekan IO (2016) Flood risk management in the coastal city of Lagos, Nigeria. Journal of Flood Risk Management 9:255–264. doi: 10.1111/jfr3.12179

Adeleye BM, Ayangbile OA (2016) Flood vulnerability: Impending danger in Sabon-Gari Minna, Niger State, Nigeria. Ethiopian Journal of Environmental Studies and Management 9:35. doi: 10.4314/ejesm.v9i1.4

Adewole IF, Agbola SB, Kasim OF (2015) Building resilience to climate change impacts after the 2011 flood disaster at the University of Ibadan, Nigeria. Environment and Urbanization 27:199–216. doi: 10.1177/0956247814547679

Afriyie K, Ganle JK, Santos E (2018) 'The floods came and we lost everything': weather extremes and households' asset vulnerability and adaptation in rural Ghana. Climate and Development 10:259–274. doi: 10.1080/17565529.2017.1291403

Agbola BS, Ajayi O, Taiwo OJ, Wahab BW (2012) The August 2011 flood in Ibadan, Nigeria: Anthropogenic causes and consequences. International Journal of Disaster Risk Science 3:207–217. doi: 10.1007/s13753-012-0021-3

Ahadzie DK, Proverbs DG (2011) Emerging issues in the management of floods in ghana. Int. J. SAFE 1:182–192. doi: 10.2495/SAFE-V1-N2-182-192

Ajaero CK (2017) A gender perspective on the impact of flood on the food security of households in rural communities of Anambra state, Nigeria. Food Security 9:685–695. doi: 10.1007/s12571-017-0695-x

Ajaero CK, Mozie AT, Abu IN (2018) Migrating from Migratory Waters to Migration of Livelihoods. Social Indicators Research 136:319–333. doi: 10.1007/s11205-016-1524-x

Ajibade I, McBean G (2014) Climate extremes and housing rights: A political ecology of impacts, early warning and adaptation constraints in Lagos slum communities. Geoforum 55:76–86. doi: 10.1016/j.geoforum.2014.05.005

Ajibade I, McBean G, Bezner-Kerr R (2013) Urban flooding in Lagos, Nigeria: Patterns of vulnerability and resilience among women. Global Environmental Change 23:1714–1725. doi: 10.1016/j.gloenvcha.2013.08.009

Akinsanola AA, Zhou W (2019) Projections of West African summer monsoon rainfall extremes from two CORDEX models. Clim Dyn 52:2017–2028. doi: 10.1007/s00382-018-4238-8

Almoradie A, Brito MM, Evers M, Bossa A, Lumor M, Norman C, Yacouba Y, Hounkpe J (2020) Current flood risk management practices in Ghana: Gaps and opportunities for improving resilience. J Flood Risk Management 13. doi: 10.1111/jfr3.12664

Antwi-Boasiako BA (2016) Insurance and flood risk reduction in Ghana: do insurers penalise homeowners who take precautionary measures? Environmental Hazards 15:343–355. doi: 10.1080/17477891.2016.1209455

Antwi-Boasiako BA (2017) It's beyond my control: The effect of locus of control orientation on disaster insurance adoption. International Journal of Disaster Risk Reduction 22:297–303. doi: 10.1016/j.ijdrr.2017.02.014

Arrighi C, Rossi L, Trasforini E, Rudari R, Ferraris L, Brugioni M, Franceschini S, Castelli F (2018) Quantification of flood risk mitigation benefits: A building-scale damage assessment through the RASOR platform. J Environ Manage 207:92–104. doi: 10.1016/j.jenvman.2017.11.017

Atidegla SC, Koumassi HD, Houssou ES (2018) Variabilité climatique et production maraîchère dans la plaine inondable d'Ahomey-Gblon au Bénin. International Journal of Biological and Chemical Sciences 11:2254. doi: 10.4314/ijbcs.v11i5.24

Badou FD, Hounkpè J, Yira Y, Ibrahim M, Bossa AY (2019) Increasing Devastating Flood Events in West Africa: Who is to Blame? In: Adegoke J, Sylla MB, Bossa AY, Ogunjobi K, Adounkpe J (eds) Regional Climate Change Series: Floods. WASCAL Publishing, Accra, Ghana, pp 84–90

Beck HE, Zimmermann N, McVicar TR, Vergopolan N, Berg A, Wood EF (2018) Present and future Köppen-Geiger climate classification maps at 1-km resolution. Scientific Data 5:180214. doi: 10.1038/sdata.2018.214

Berrang-Ford L, Ford JD, Paterson J (2011) Are we adapting to climate change? Global Environmental Change 21:25–33. doi: 10.1016/j.gloenvcha.2010.09.012

Berrang-Ford L, Pearce T, Ford JD (2015) Systematic review approaches for climate change adaptation research. Regional Environmental Change 15:755–769. doi: 10.1007/s10113-014-0708-7

Biconne R (2014) Knowledge Sharing on Climate Change as a Resource for Adaptation Processes: The Case of Malika, Senegal. In: Macchi S, Tiepolo M (eds) Climate Change Vulnerability in Southern African Cities. Springer International Publishing, Cham, pp 125–140

Biesbroek R, Berrang-Ford L, Ford JD, Tanabe A, Austin SE, Lesnikowski A (2018) Data, concepts and methods for large- n comparative climate change adaptation policy research: A systematic literature review. Wiley Interdiscip Rev Clim Change 9:e548. doi: 10.1002/wcc.548

Boamah S, Armah F, Kuuire V, Ajibade I, Luginaah I, McBean G (2015) Does Previous Experience of Floods Stimulate the Adoption of Coping Strategies? Evidence from Cross Sectional Surveys in Nigeria and Tanzania. Environments 2:565–585. doi: 10.3390/environments2040565

Bonye SZ, Godfred JS (2011) Traditional coping mechanisms in disaster management in the Builsa and Sissala districts of Northern Ghana. European Journal of Social Sciences 25:204–218

Bottazzi P, Winkler M, Boillat S, Diagne A, Maman Chabi Sika M, Kpangon A, Faye S, Speranza C (2018) Measuring Subjective Flood Resilience in Suburban Dakar: A Before–After Evaluation of the “Live with Water” Project. Sustainability 10:2135. doi: 10.3390/su10072135

Bottazzi P, Winkler MS, Ifejika Speranza C (2019) Flood governance for resilience in cities: The historical policy transformations in Dakar’s suburbs. Environmental Science & Policy 93:172–180. doi: 10.1016/j.envsci.2018.12.013

Campion BB, Venzke J-F (2013) Rainfall variability, floods and adaptations of the urban poor to flooding in Kumasi, Ghana. Natural Hazards 65:1895–1911. doi: 10.1007/s11069-012-0452-6

Carrick J, Abdul R., Rahim, M. S. A. B. A., Adjei C, Kalee HHA, Banks SJ, Bolam FC, Campos L. IM, Clark B, Cowton J, Domingos IFN, Golicha DD, Gupta G, Grainger M, Hasanaliyeva G, Hodgson DJ, Lopez-Capel E, Magistrali AJ, Merrell IG, Oikeh I, Othman MS, Ranathunga M., Thilanka K. R., Samuel CWC, Sufar EKH, Watson PA, Zakaria NNAB, Stewart G (2019) Is planting trees the solution to reducing flood risks? Journal of Flood Risk Management 12:635. doi: 10.1111/jfr3.12484

Challies E, Newig J, Thaler T, Kochskämper E, Levin-Keitel M (2016) Participatory and collaborative governance for sustainable flood risk management: An emerging research agenda. Environmental Science & Policy 55:275–280. doi: 10.1016/j.envsci.2015.09.012

Cirella G, Iyalomhe F (2018) Flooding Conceptual Review: Sustainability-Focalized Best Practices in Nigeria. Applied Sciences 8:1558. doi: 10.3390/app8091558

Cirella G, Iyalomhe F, Adekola P (2019) Determinants of Flooding and Strategies for Mitigation: Two-Year Case Study of Benin City. Geosciences 9:136. doi: 10.3390/geosciences9030136

Coker AA, Adebayo CO, Odoemena BC, Akogun EO, Ezinne CG (2014) Flood and cassave productivity in Kogi State, Nigeria: A quantitative analysis using cross-sectional data. Ethiopian Journal of Environmental Studies and Management 7:599. doi: 10.4314/ejesm.v7i6.2

Danso SY, Addo IY (2017) Coping strategies of households affected by flooding: A case study of Sekondi-Takoradi Metropolis in Ghana. Urban Water Journal 14:539–545. doi: 10.1080/1573062X.2016.1176223

DIVA GIS (2020) Download data by country. https://diva-gis.org/gdata. Accessed 20 Aug 2020

Dosio A, Jones RG, Jack C, Lennard C, Nikulin G, Hewitson B (2019) What can we know about future precipitation in Africa? Robustness, significance and added value of projections from a large ensemble of regional climate models. Clim Dyn 53:5833–5858. doi: 10.1007/s00382-019-04900-3

Dunning C, Black E (2018) Later Wet Seasons with More Intense Rainfall over Africa under Future Climate Change. Journal of Climate 31:9719–9738

Echendu AJ (2020) The impact of flooding on Nigeria's sustainable development goals (SDGs). Ecosystem Health and Sustainability 6:1791735. doi: 10.1080/20964129.2020.1791735

ECOWAS (2020) Member states. https://www.ecowas.int/member-states/. Accessed 27 Oct 2020

Egbinola CN, Olaniran HD, Amanambu AC (2017) Flood management in cities of developing countries: the example of Ibadan, Nigeria. Journal of Flood Risk Management 10:546–554. doi: 10.1111/jfr3.12157

El Zowalaty ME, Järhult JD (2020) From SARS to COVID-19: A previously unknown SARS- related coronavirus (SARS-CoV-2) of pandemic potential infecting humans - Call for a One Health approach. One health (Amsterdam, Netherlands) 9:100124. doi: 10.1016/j.onehlt.2020.100124

EM-Dat (2020) The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir. https://www.emdat.be/emdat_db/. Accessed 24 Mar 2020

Enete AA, Obi JN, Ozor N, Mba CL (2016) Socioeconomic assessment of flooding among farm households in Anambra state, Nigeria. International Journal of Climate Change Strategies and Management 8:96–111. doi: 10.1108/IJCCSM-07-2014-0084

Epule TE, Ford JD, Lwasa S, Lepage L (2017) Climate change adaptation in the Sahel. Environmental Science & Policy 75:121–137. doi: 10.1016/j.envsci.2017.05.018

ERCC (2020) West and Central Africa | Floods. https://erccportal.jrc.ec.europa.eu/ercmaps/ECDM_20200916_West-Central-Africa_Floods.pdf. Accessed 25 Sep 2020

EU (2007) Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks

Evadzi PIK, Scheffran J, Zorita E, Hünicke B (2018) Awareness of sea-level response under climate change on the coast of Ghana. Journal of Coastal Conservation 22:183–197. doi: 10.1007/s11852-017-0569-6

Evers M, Jonoski A, Almoradie A, Lange L (2016) Collaborative decision making in sustainable flood risk management: A socio-technical approach and tools for participatory governance. Environmental Science & Policy 55:335–344. doi: 10.1016/j.envsci.2015.09.009

Ford JD, McDowell G, Jones J (2014) The state of climate change adaptation in the Arctic. Environmental Research Letters 9:104005. doi: 10.1088/1748-9326/9/10/104005

Ford JD, Stephenson E, Cunsolo Willox A, Edge V, Farahbakhsh K, Furgal C, Harper S, Chatwood S, Mauro I, Pearce T, Austin S, Bunce A, Bussalleu A, Diaz J, Finner K, Gordon A, Huet C, Kitching K, Lardeau M-P, McDowell G, McDonald E, Nakoneczny L, Sherman M (2016) Community-based adaptation research in the Canadian Arctic. Wiley Interdiscip Rev Clim Change 7:175–191. doi: 10.1002/wcc.376

Frick-Trzebitzky F (2017) Crafting adaptive capacity: Institutional bricolage in adaptation to urban flooding in Greater Accra. Water Alternatives 10:625–647

Frick-Trzebitzky F, Bruns A (2019) Disparities in the implementation gap: adaptation to flood risk in the Densu Delta, Accra, Ghana. Journal of Environmental Policy & Planning 21:577–592. doi: 10.1080/1523908X.2017.1343136

Glago FJ (2019) Household disaster awareness and preparedness: A case study of flood hazards in Asamankese in the West Akim Municipality of Ghana. Jamba (Potchefstroom, South Africa) 11:789. doi: 10.4102/jamba.v11i1.789

Grabs W, Tyagi AC, Hyodo M (2007) Integrated flood management. Water Sci Technol 56:97–103. doi: 10.2166/wst.2007.541

Güneralp B, Güneralp İ, Liu Y (2015) Changing global patterns of urban exposure to flood and drought hazards. Global Environmental Change 31:217–225. doi: 10.1016/j.gloenvcha.2015.01.002

Hagenlocher M, Meza I, Anderson CC, Min A, Renaud FG, Walz Y, Siebert S, Sebesvari Z (2019) Drought vulnerability and risk assessments: state of the art, persistent gaps, and research agenda. Environ. Res. Lett. 14:83002. doi: 10.1088/1748-9326/ab225d

Hartmann T, Albrecht J (2014) From Flood Protection to Flood Risk Management: Condition-Based and Performance-Based Regulations in German Water Law. Journal of Environmental Law 26:243–268. doi: 10.1093/jel/equ015

Hetcheli F (2013) Risques pluviométriques et nouvelles orientations des agriculteurs du canton de Togblékopé (basse vallée de Zio) au Togo. Journal de la Recherche Scientifique de l'Université de Lomé, Série B 15:135–149

Holmes EA, O'Connor RC, Perry VH, Tracey I, Wessely S, Arseneault L, Ballard C, Christensen H, Cohen Silver R, Everall I, Ford T, John A, Kabir T, King K, Madan I, Michie S, Przybylski AK, Shafran R, Sweeney A, Worthman CM, Yardley L, Cowan K, Cope C, Hotopf M, Bullmore E (2020) Multidisciplinary research priorities for the COVID-19 pandemic: a call for action for mental health science. The Lancet Psychiatry 7:547–560. doi: 10.1016/S2215-0366(20)30168-1

Ibitoye MO, Komolafe AA, Adegboyega AS, Adebola AO, Oladeji OD (2019) Analysis of vulnerable urban properties within river Ala floodplain in Akure, Southwestern Nigeria. Spatial Information Research. doi: 10.1007/s41324-019-00298-6

IMF (2020) Policy responses to Covid-19. https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19. Accessed 10 Jun 2020

Kablan AKM, Dongo K, Fokou G, Coulibaly M (2019) Assessing population perception and socioeconomic impact related to flood episodes in urban Côte d'Ivoire. International Journal of Biological and Chemical Sciences 13:2210. doi: 10.4314/ijbcs.v13i4.26

Kamara JK, Akombi BJ, Agho K, Renzaho AMN (2018) Resilience to Climate-Induced Disasters and Its Overall Relationship to Well-Being in Southern Africa: A Mixed-Methods Systematic Review. Int J Environ Res Public Health 15. doi: 10.3390/ijerph15112375

Kielland A (2016) The Role of Risk Perception in Child Mobility Decisions in West Africa, Empirical Evidence From Benin. World Development 83:312–324. doi: 10.1016/j.worlddev.2016.01.008

Komi K, Amisigo B, Diekkrüger B (2016) Integrated Flood Risk Assessment of Rural Communities in the Oti River Basin, West Africa. Hydrology 3:42. doi: 10.3390/hydrology3040042

Lesnikowski AC, Ford JD, Berrang-Ford L, Barrera M, Heymann J (2015) How are we adapting to climate change? A global assessment. Mitigation and Adaptation Strategies for Global Change 20:277–293. doi: 10.1007/s11027-013-9491-x

Lokonon BOK (2016) Urban households' attitude towards flood risk, and waste disposal: Evidence from Cotonou. International Journal of Disaster Risk Reduction 19:29–35. doi: 10.1016/j.ijdrr.2016.08.015

Ludy J, Kondolf GM (2012) Flood risk perception in lands "protected" by 100-year levees. Natural Hazards 61:829–842. doi: 10.1007/s11069-011-0072-6

Mahe G, Lienou G, Descroix L, Bamba F, Paturel JE, Laraque A, Meddi M, Habaieb H, Adeaga O, Dieulin C, Chahnez Kotti F, Khomsi K (2013) The rivers of Africa: witness of climate change and human impact on the environment. Hydrological Processes 27:2105–2114. doi: 10.1002/hyp.9813

Markantonis V, Farinosi F, Dondeynaz C, Ameztoy I, Pastori M, Marletta L, Ali A, Carmona Moreno C (2018) Assessing floods and droughts in the Mékrou River basin (West Africa): a combined household survey and climatic trends analysis approach. Natural Hazards and Earth System Sciences 18:1279–1296. doi: 10.5194/nhess-18-1279-2018

Mbow C, Diop A, Diaw AT, Niang CI (2008) Urban sprawl development and flooding at Yeumbeul suburb (Dakar-Senegal). African Journal of Environmental Science and Technology 2

Mengist W, Soromessa T, Legese G (2020) Method for conducting systematic literature review and meta-analysis for environmental science research. MethodsX 7:100777. doi: 10.1016/j.mex.2019.100777

Milman A, Warner BP, Chapman DA, Short Gianotti AG (2018) Identifying and quantifying landowner perspectives on integrated flood risk management. Journal of Flood Risk Management 11:34–47. doi: 10.1111/jfr3.12291

Ngwese NM, Saito O, Sato A, Agyeman Boafo Y, Jasaw G (2018) Traditional and Local Knowledge Practices for Disaster Risk Reduction in Northern Ghana. Sustainability 10:825. doi: 10.3390/su10030825

Nicola M, Alsafi Z, Sohrabi C, Kerwan A, Al-Jabir A, Iosifidis C, Agha M, Agha R (2020) The socio-economic implications of the coronavirus pandemic (COVID-19): A review. International journal of surgery (London, England) 78:185–193. doi: 10.1016/j.ijsu.2020.04.018

Nkwunonwo UC, Whitworth M, Baily B (2016) Review article: A review and critical analysis of the efforts towards urban flood risk management in the Lagos region of Nigeria. Nat. Hazards Earth Syst. Sci. 16:349–369. doi: 10.5194/nhess-16-349-2016

Nordbeck R, Steurer R, Löschner L (2019) The future orientation of Austria's flood policies: from flood control to anticipatory flood risk management. Journal of Environmental Planning and Management 62:1864–1885. doi: 10.1080/09640568.2018.1515731

Ntajal J, Lamptey BL, Mahamadou IB, Nyarko BK (2017) Flood disaster risk mapping in the Lower Mono River Basin in Togo, West Africa. International Journal of Disaster Risk Reduction 23:93–103. doi: 10.1016/j.ijdrr.2017.03.015

Odemerho FO (2015) Building climate change resilience through bottom-up adaptation to flood risk in Warri, Nigeria. Environment and Urbanization 27:139–160. doi: 10.1177/0956247814558194

Oladokun VO, Proverbs D (2016) Flood risk management in Nigeria: a review of the challenges and opportunities. Int. J. SAFE 6:485–497. doi: 10.2495/SAFE-V6-N3-485-497

Olanrewaju CC, Chitakira M, Olanrewaju OA, Louw E (2019) Impacts of flood disasters in Nigeria: A critical evaluation of health implications and management. Jamba (Potchefstroom, South Africa) 11:557. doi: 10.4102/jamba.v11i1.557

Olokesusi F, Olorunfemi FB, Onwuemele A, Oke MO (2015) Awareness of and Responses to the 2011 Flood Warnings Among Vulnerable Communities in Lagos, Nigeria. In: Werlen B (ed) Global Sustainability. Springer International Publishing, Cham, pp 203–223

Onu B, Price T, Surendran SS, Timbiri A (2013) Peoples' perception on the effects of flood in the riverine areas of Ogbia Local Government Area of Bayelsa State, Nigeria. Knowledge Management 12:21–44

Osayomi T, Oladosu OS (2016) "Expect more floods in 2013": An analysis of flood preparedness in the flood prone city of Ibadan, Nigeria. African Journal of Sustainable Development 6

Osman A, Nyarko BK, Mariwah S (2016) Vulnerability and risk levels of communities within Ankobra estuary of Ghana. International Journal of Disaster Risk Reduction 19:133–144. doi: 10.1016/j.ijdrr.2016.08.016

Ottah GA (2017) Impact of Radio Kogi's flood disaster awareness campaign on residents of Ibaji Local Government Area of Kogi State, Nigeria. International Journal of Arts and Humanities 6:80. doi: 10.4314/ijah.v6i3.7

Ouikotan RB, van der Kwast J, Mynett A, Afouda A (eds) (2017) Gaps and challenges of flood risk management in West African coastal cities

Owen G (2020) What makes climate change adaptation effective? A systematic review of the literature. Global Environmental Change 62:102071. doi: 10.1016/j.gloenvcha.2020.102071

Owusu Twum K, Abubakari M (2019) Cities and floods: A pragmatic insight into the determinants of households' coping strategies to floods in informal Accra, Ghana. Jamba (Potchefstroom, South Africa) 11:608. doi: 10.4102/jamba.v11i1.608

Oyekale AS, Oladele OI, Mukela F (2013) Impacts of flooding on coastal fishing folks and risk adaptation behaviours in Epe, Lagos State. Afr. J. Agric. Res. 8:3392–3405. doi: 10.5897/AJAR12.730

Oyerinde GT, Lawin EA, Odofin AJ (2017) Farmers' Responses to Changing Hydrological Trends in the Niger Basin Parts of Benin. Hydrology 4:52. doi: 10.3390/hydrology4040052

Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, McGuinness LA, Stewart LA, Thomas J, Tricco AC, Welch VA, Whiting P, Moher D (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 372:n71. doi: 10.1136/bmj.n71

Plate EJ (2002) Flood risk and flood management. Journal of Hydrology 267:2–11

Roos MM, Hartmann TT, Spit TT, Johann GG (2017) Constructing risks – Internalisation of flood risks in the flood risk management plan. Environmental Science & Policy 74:23–29. doi: 10.1016/j.envsci.2017.04.007

Saidu I (2009) An analysis of Loko flood disaster resettlement scheme, in Song Local Government Area of Adamawa State, Nigeria. Journal of the Environment 4:19–27

Sayers P, Li Y, Galloway G, Penning-Rowsell E, Shen F, Wen K, Chen Y, Le Quesne T (2013) Flood risk management: A Strategic Approach. UNESCO, Paris

Schaer C (2015) Condemned to live with one's feet in water? International Journal of Climate Change Strategies and Management 7:534–551. doi: 10.1108/IJCCSM-03-2014-0038

Schaer C, Hanonou EK (2017) The Real Governance of Disaster Risk Management in Peri-urban Senegal. Progress in Development Studies 17:38–53. doi: 10.1177/1464993416674301

Schlef KE, Kaboré L, Karambiri H, Yang YE, Brown CM (2018) Relating perceptions of flood risk and coping ability to mitigation behavior in West Africa: Case study of Burkina Faso. Environmental Science & Policy 89:254–265. doi: 10.1016/j.envsci.2018.07.013

Serpantié G, Dorée A, Fusillier J-L, Moity-Maizi P, Lidon B, Douanio M, Sawadogo A, Bossa AY, Hounkpè J (2019) Nouveaux risques dans les bas-fonds des terroirs soudaniens. Une étude de cas au Burkina Faso. Cah. Agric. 28:19. doi: 10.1051/cagri/2019020

Shaffril HAM, Krauss SE, Samsuddin SF (2018) A systematic review on Asian's farmers' adaptation practices towards climate change. Science of the total environment 644:683–695. doi: 10.1016/j.scitotenv.2018.06.349

Siddaway AP, Wood AM, Hedges LV (2019) How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses. Annu Rev Psychol 70:747–770. doi: 10.1146/annurev-psych-010418-102803

Thomas F, Knüppe K (2016) From Flood Protection to Flood Risk Management: Insights from the Rhine River in North Rhine-Westphalia, Germany. Water Resources Management 30:2785–2800. doi: 10.1007/s11269-016-1323-9

Tiepolo M, Rosso M, Massazza G, Belcore E, Issa S, Braccio S (2019) Flood Assessment for Risk-Informed Planning along the Sirba River, Niger. Sustainability 11:4003. doi: 10.3390/su11154003

UN (1989) International Decade for Natural Disaster Reduction. Resolutions adopted on the reports of the Second Committee. https://undocs.org/A/RES/44/236. Accessed 09 May 2020

UN (2005) Report of the World Conference on Disaster Reduction Kobe, Hyogo, Japan, 18-22 January 2005

UN (2015) Sendai Framework for Disaster Risk Reduction 2015 – 2030

UN OCHA (2007) West Africa - Floods. https://reliefweb.int/sites/reliefweb.int/files/resources/FDBC0DD4783141E385257378004811DF-ocha_FL_afr071017.pdf. Accessed 25 Sep 2020

UN OCHA (2009) West Africa - Flood affected population - June to September 2009. https://reliefweb.int/sites/reliefweb.int/files/styles/report-large/public/resources-pdf-previews/15744-14D93E78C3482C2F8525764200666310-map.png?itok=prnIuu-q. Accessed 25 Sep 2020

UN OCHA (2010) West Africa - Flood impact profile. http://www.un-spider.org/sites/default/files/images/Dieye_Fig.2.gif. Accessed 25 Sep 2020

UN OCHA (2012) West and Central Africa: Floods situation (as of 15 Oct 2012). https://reliefweb.int/sites/reliefweb.int/files/resources/map_3086.pdf. Accessed 25 Sep 2020

UN OCHA (2016) West Africa: Impact of the floods. https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/wca_a4_l_impact_of_floods_20160822.pdf. Accessed 25 Sep 2020

UNDRR (2020a) Residual risk. https://www.undrr.org/terminology/residual-risk. Accessed 26 Mar 2020

UNDRR (2020b) Risk transfer. https://www.undrr.org/terminology/risk-transfer. Accessed 10 Jul 2020

VERBI (2021) What is MAXQDA? https://www.maxqda.com/what-is-maxqda. Accessed 04 Jan 2021

Vissin EW, Hedible S, Amoussou E, Totin HS, Odoulami L, Etene C, Boko M, Blivi A (2016) Variabilité climatique et hydrologique dans la Basse Vallée de l'Oumémé à Bonou. Journal de la Recherche Scientifique de l'Université de Lomé, Série B 18:69–81

Vizy EK, Cook KH (2012) Mid-Twenty-First-Century Changes in Extreme Events over Northern and Tropical Africa. Journal of Climate 25:5748–5767. doi: 10.1175/JCLI-D-11-00693.1

Wahab B, Falola O (2017) The consequences and policy implications of urban encroachment into flood-risk areas: the case of Ibadan. Environmental Hazards 16:1–20. doi: 10.1080/17477891.2016.1211505

Wellens K, Terpstra T, Maeyer P de (2013) Perception and communication of flood risks: a systematic review of empirical research. Risk Anal 33:24–49. doi: 10.1111/j.1539-6924.2012.01844.x

WMO (2009) Integrated flood management. Concept Paper. WMO-No.1047

Young HR, Cornforth RJ, Gaye AT, Boyd E (2019) Event Attribution science in adaptation decision-making: the context of extreme rainfall in urban Senegal. Climate and Development 11:812–824. doi: 10.1080/17565529.2019.1571401

3. Recovering from Financial Implications of Flood Impacts—The Role of Risk Transfer in the West African Context (Second academic journal publication)

Published originally as: Wagner S, Thiam S, Dossoumou NIP, Hagenlocher M, Souvignet M, Rhyner J. Recovering from Financial Implications of Flood Impacts—The Role of Risk Transfer in the West African Context. Sustainability. 2022; 14(14):8433. https://doi.org/10.3390/su14148433

Abstract: In many West African river basins, households regularly experience floods and the associated impacts. In the absence of widely accessible formal risk transfer mechanisms (e.g., insurance), households often have to cope with financial impacts. Only a few studies have explored the financial effects of floods on agriculture-dependent households in the region and the role formal and informal risk transfer plays in their mitigation. This study addresses this gap, explores flood impacts with financial implications for households, and researches the existing strategies to mitigate them. Moreover, it aims to better understand how different measures influence the recovery process. The study draws on primary data from a household survey (n = 744) in the Lower Mono River basin, combined with stakeholder workshops and semi-structured interviews, and applies a generalized linear model to the survey data. The results reveal four flood impact types with financial implications: agricultural, material, health, and trade. Moreover, a shortened recovery time is significantly associated with assistance from savings groups and cooperatives—groups originally not formed to help during floods. In light of the severe and frequent flood impacts, effective and publicly accepted adaptation measures are needed to enable favorable conditions for creating sustainable and accessible risk transfer mechanisms.

Keywords: financial; flood impacts; households; risk transfer; coping; insurance; recovery; Togo; Benin

3.1 Introduction

In the past decades, flood events in West Africa have become increasingly devastating (Badou et al. 2019). Numerous river basins in West Africa, such as the Niger, Volta, Oti, or Mono basins, are at high risk of flooding (Amoussou et al. 2020, Aich et al. 2016, Komi et al. 2016a, Komi et al. 2016b). The population in these areas commonly experiences fatalities caused by flooding and is affected by widespread material damage, displacement, and interruption of livelihood activities (Floodlist 2020a, Floodlist 2020b, Floodlist 2020c, Floodlist 2019). Moreover, the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) observed a trend of more frequent occurrences of river floods in West Africa since the 1980s and projected increased monsoon precipitation coupled with a delayed onset and retreat for the future (Masson-Delmotte et al. 2021). Other trends that exacerbate the problem of floods in the region are settlement expansion into flood risk zones (Tiepolo

et al. 2021, Güneralp et al. 2015), deforestation through mangrove loss (Padonou et al. 2021), and land-use change of large areas of forest and other naturalized areas into cropland or settlements (Asenso Barnieh et al. 2020). Given the perennial reoccurrence of flood events in the area, new and more intensified flood risk management efforts are required (Okoye 2021).

Flood impacts in the region span across various categories, including damage to buildings, health impacts, loss of livelihoods and income, environmental degradation, displacement, lack of food and drinking water, interruption of social activities, and constrained mobility (Yadzani et al. 2022, Wagner et al. 2021). Generally, in various tropical countries, there is a lack of baseline/reference information with regard to impact and risk assessments, requiring many to resort to using existing (and low-cost) data (Quesada-Román 2022, Pinos & Quesada-Román 2022, Granados-Bolaños et al. 2021). Similarly, information on financial damages of flood events in West Africa is relatively sparse, and publicly accessible regional or national disaster inventories are lacking. In addition, other existing databases, such as EM-DAT, only register direct damage to property, crops, and livestock (EM-Dat 2021). Addressing these practical gaps, a number of recent studies have started to explore the financial implications of flood impacts in the region and how they unfold at the household level. For example, Ajibade et al. (2013) qualitatively assessed how flood impacts intersect with gender and socio-economic status at the household level. Afriyie et al. (2018) explored the vulnerability of natural, physical, social, financial, and human assets to shocks such as floods and adaptation strategies in the broader sense from a livelihood perspective by carrying out focus group discussions. In addition, Kheradmand et al. (2018) estimated the economic damages to households in terms of residential house damage in different dike height scenarios by combining flood hazard and asset maps. However, existing research has not yet determined how much the various dimensions of flood impacts (e.g., agricultural, health, business interruption, etc.) actually cost households.

One way to mitigate the financial impacts of flooding is through risk transfer, such as insurance (Mai et al. 2020, Haer et al. 2019). Though case studies of flood risk management in West Africa recommend such risk transfer, it does not play a significant role yet in the region (Wagner et al. 2021). Currently, academic literature addressing risk transfer for floods generally focuses on formal mechanisms, such as insurance and public risk pools (Mai et al. 2020, Kron et al. 2019, Hochrainer-Stigler et al. 2017, Prettenthaler et al. 2017, Thieken et al. 2016, Surminski & Oramas-Dorta 2014, Jongman et al. 2014, Treby et al. 2006); it pays limited attention to other forms of risk transfer. The academic literature addressing informal risk transfer arrangements in the context of floods is an exception to this. One example worth mentioning are experimentally formed risk-sharing groups in Bangladesh that showed

that disaster-affected members were less likely to drop out of risk-sharing groups than non-affected members (Islam et al. 2020). Moreover, a study found that households with at least one member being part of a savings group in Dar es Salaam, Tanzania, recovered faster financially than households without a member in such groups (Panman et al. 2021). In reference to climate-related disasters in general, Hallegatte et al. (2016) stated that poorer households often have access only to social protection mechanisms, such as government assistance and support from Non-Governmental Organizations (NGOs), in times of a disaster with larger severity, while richer households can access insurance or accumulate savings. Still, a relative sparseness of research that focuses on the context of floods can be observed. A reason for this could be the perceived inability of such arrangements to address large-scale events such as floods, which are likely to affect a major share of or even the entire risk-sharing community (Germanwatch & MCII 2020). Nevertheless, existing flood risk-related research suggests the importance of mutual support activities in the response process after flood events in the West African region (Wagner et al. 2021). However, whether such support activities also go beyond reconstruction aid remains unclear. In addition, it is not clear whether these activities take place in the financial domain and can be classified as risk transfer mechanisms (Wagner et al. 2021). It is relevant to assess whether the existing ways of dealing with financial implications from flood impacts can significantly contribute to the financial recovery process. This analysis will indicate the current state of the risk transfer landscape and the necessity for and the feasibility of creating a potential flood insurance mechanism to complement the existing measures. As a consequence, this research will contribute to finding more sustainable ways of financial risk management in the research area.

To address to previously outlined research gaps, this study addresses which types of flood impacts cause financial consequences for households. Moreover, this study explores the measures through which financial consequences from flood impacts are mitigated as well as their contribution to the financial recovery process. Within those measures, the role of risk transfer is examined with a specific focus. We aimed to shed light on the need for a potential flood insurance product in the research area that considers flood impacts with financial implications and complements the established practices of addressing such impacts. The following research questions were addressed:

(1) What are the flood impacts with financial implications for households?
(2) What measures are available to households to address these impacts, and can they be classified as risk transfer?
(3) How long do affected households take, on average, to recover financially from various types of flood impacts with financial implications?

(4) What are the associations of existing measures with financial recovery, and what are the limitations of such measures?

We first provide background information about the current state-of-the-art on floods and risk transfer in the research area. Subsequently, we describe the methodological approach for data collection and analysis. Then, the results are presented in the order of the previously outlined research questions and discussed in relation to other academic literature. Finally we provide a concise take-home message derived from the discussion of the results.

3.2 Background

3.2.1 Risk Transfer

Risk transfer describes "shifting the financial consequences of particular risks from one party to another, whereby a household, community, enterprise or State authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party" (UNDRR 2021, n.p.). It can be distinguished from risk retention, external financing, and emergency assistance, and as an ex-ante instrument, it involves an agreement between parties before a disastrous event (Cissé 2021). Risk transfer mechanisms are central to managing the financial implications of flood impacts (Radermacher et al. 2006) and can be either formal or informal (UNDRR 2021). While formal risk transfer mechanisms mostly come in the form of insurance contracts, catastrophe bonds, contingent credit facilities, or reserve funds, informal risk transfer occurs within networks of families or communities and involves sharing of gifts or credits between its members (UNDRR 2021). Such arrangements, sometimes referred to as risk sharing, are seen to be more context-specific, to entail fewer transaction costs, to be more flexible and affordable, to be based on trust, and to be adaptable to local conditions (Panman et al. 2021, Germanwatch & MCII 2020). Table 3.1 shows an overview of the common aspects of risk transfer based on UNDRR (2021) and Cissé (2021).

In the field of Disaster Risk Reduction, it is well known that despite extensive efforts in risk reduction, a certain level of residual risk will most likely exist as a baseline (Schinko et al. 2019). In some cases, this risk is chosen not to be addressed, due to, for example, the residual risk level being socially accepted or the costs of risk reduction being higher than the cost of the expected damage (Bouwer 2019). In flood-related research from developed economies, such debates mostly revolve around the implementation of structural control measures, their protection gaps and potential failure (Ridolfi et al. 2019, Tourment et al. 2017, Pinter et al. 2016), as well as the coverage of such risks by insurance (Christopher 2019, Surminski & Eldridge 2017, Thomas & Leichenko 2011). However, especially in the

context of developing economies, efforts in flood risk reduction are not well developed, and the population is often exposed to a high level of risk, affecting their financial achievements, among other impacts (Wagner et al. 2021). Still, informal risk transfer mechanisms allow the exposed population in such areas to alleviate the financial impacts of disaster events at least to a certain extent (Panman et al. 2020, Germanwatch & MCII 2020). In light of the projected climatic changes and subsequent extreme events, in particular, floods the West African region (Masson-Delmotte et al. 2021), the question remains whether such mechanisms can be sustainable in the long run.

Table 3.1. Aspects of risk transfer

(based on UNDRR (2021) and Cissé (2021)).

Involved parties	Coverage of	Types	Conditions	Exchanges
- Party 1 (transferring the risk) - -Party 2 (accepting the risk)	- Financial consequences of particular (specified) risks	- Formal (e.g., insurance, Cat Bonds, contingent credits, or funds) - Informal ("risk sharing" through provision gifts or credits between family or community members)	- Agreement with another party before a disastrous event occurs (explicitness of agreement usually stronger for formal than for informal arrangements) - Mutual exchange of resources/benefits between parties	- Party 2 receives continuous or compensatory social or financial benefits from Party 1 in exchange for accepting the risk - Party 1 receives (financial) resources from Party 2 after a disaster occurs

3.2.2 Case Study Area: Lower Mono River Basin

The Lower Mono River basin (LMRB), a transboundary river basin shared between Togo and Benin (Figure 3.1, has experienced flood events in both countries in the past decade, including in 2007 (UN OCHA 2007a, UN OCHA 2007b), 2010 (United Nations 2010, United Nations Economic Commission for Africa 2015), 2019 (Vert Togo 2019, Hounkpêvi 2019), 2021 (Vigan 2021, Agence Benin Presse 2021). Currently, floods in the basin have become such a problem that they occur almost on a yearly basis in varying intensities (Ntajal et al. 2017). The hydrology of the LMRB was modified by the construction of the Nangbeto Dam in 1987 (Ntajal et al. 2017) for hydropower generation and as a water reservoir to be used for fishing and irrigation (African Development Bank 1995). While the Dam was found to

have a low influence on the regulation of floods, especially during times of peak flow (Amoussou et al. 2014), the periodic opening of the reservoir seems to have played an essential role in the generation of downstream floods, especially in the view of the affected population (Parkoo et al. 2022, Mike 2021, Nato 2021, Hounkpêvi 2019, Ntajal et al. 2017, Toussounon 2010). The precipitation maxima within the area are characterized by two peaks in May and October in the South of the basin and from May to September around the area of the Nangbeto reservoir (Hounguè et al. 2021). Moreover, in the light of climate change, the annual maxima of daily precipitation in the area are expected to increase further, leading to a more substantial impact of heavy rainfall events on discharge within the river basin and thus to flood events of higher severity (Amoussou et al. 2020). Apart from climatic changes, there are also other anthropogenic factors contributing to the flooding problem in the area, such as deforestation as well as the expansion of settlements, farmland, and infrastructure into exposed areas (Wetzel et al. 2022, Thiam et al. 2022, Ntajal et al. 2017).

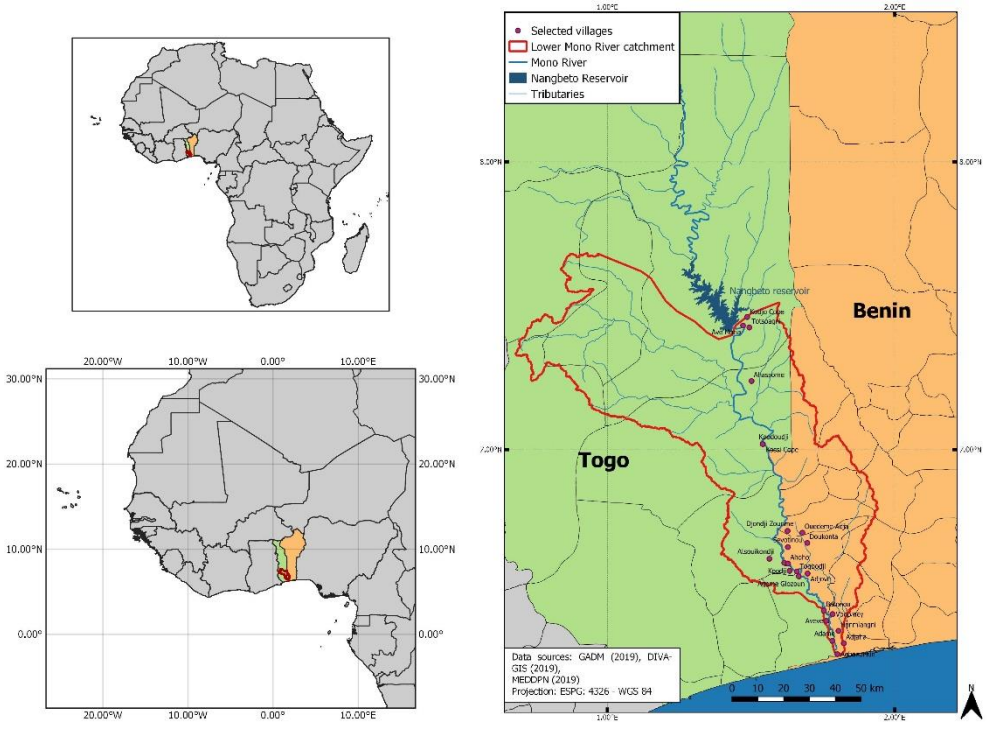


Figure 3.1 Research area with villages selected for household survey

The floods in the largely rural LMRB usually cause extensive damage, for example, to houses, infrastructure, public buildings, and human health, due to the flood water remaining in the living environment for some time (Vigan 2021, Agence Benin Presse 2021, Floodlist 2019). Additionally, they affect the livelihoods and the productive assets of the population, who largely depend on agriculture as their primary livelihood source, followed by fishing, trading, palm oil production, and keeping livestock (Wetzel et al. 2022, The World Bank 2018, Kissi et al. 2015). These impacts put an additional strain on the affected population's finances, and they are often left to figure out ways of dealing with

the flood impacts in the long term with limited resources (Agbédoufio 2020), aside from disaster assistance and relief activities by the government and NGOs. In particular, financial damages that can be addressed with risk transfer mechanisms have gained increasing attention through the political momentum of the G7 InsuResilience Initiative and the subsequent InsuResilience Global Partnership (Deutsche Klimafinanzierung 2021). The latter aims at raising the number of persons insured against climate and disaster shocks globally to 500 million by 2025 in the light of loss and damage experienced by climate change (InsuResilience Global Partnership 2021). Despite the devastating impacts arising from floods in the region, the application of formal risk transfer mechanisms, such as insurance, for these impacts are not yet widely prevalent in West Africa in general (Wagner et al. 2021), Togo Komi et al. 2016a), and Benin (Meton 2019, Lokonon 2016).

In the absence of widespread access to such formal risk transfer mechanisms, informal or partly informal mechanisms are more likely to fill the void. For example, support from social networks, in the form of providing emotional, financial, or material support, as well as access to money, food, shelter, and labor, for affected family members or friends have been found to play a crucial role in coping with and recovering from flood impacts in the West African region (Wagner et al. 2021). Similarly, for the Togolese part of the LMRB, Clubs des Mères (CM) were identified to have high importance in evacuating flood victims as well as in supporting their recovery process (Ntajal et al. 2017). The CMs are organized by the Red Cross and are a well-known example of a women's group, which, aside from their other support activities, possesses a solidarity fund that covers unforeseen health expenses on a loan basis (Livelihood Centre 2018). Nevertheless, such arrangements could be unable to address large-scale events such as floods, which are likely to affect a large share of or even the entire risk-sharing community (Germanwatch & MCII 2020). In this context, it is crucial to investigate the existing mechanisms, both formal and informal, to cope with financial flood impacts and showcase if they portray some form of risk transfer.

3.2.3 Data Collection and Analysis

This study applied a mixed-methods approach to shape the quantitative data collection based on previously collected qualitative insights in the domain of financial coping strategies on the local level (Figure 3.2). Therefore, the study started out qualitatively, with stakeholder workshops and semi-structured interviews. Based on these, a household survey was carried out to further analyze the findings quantitatively.

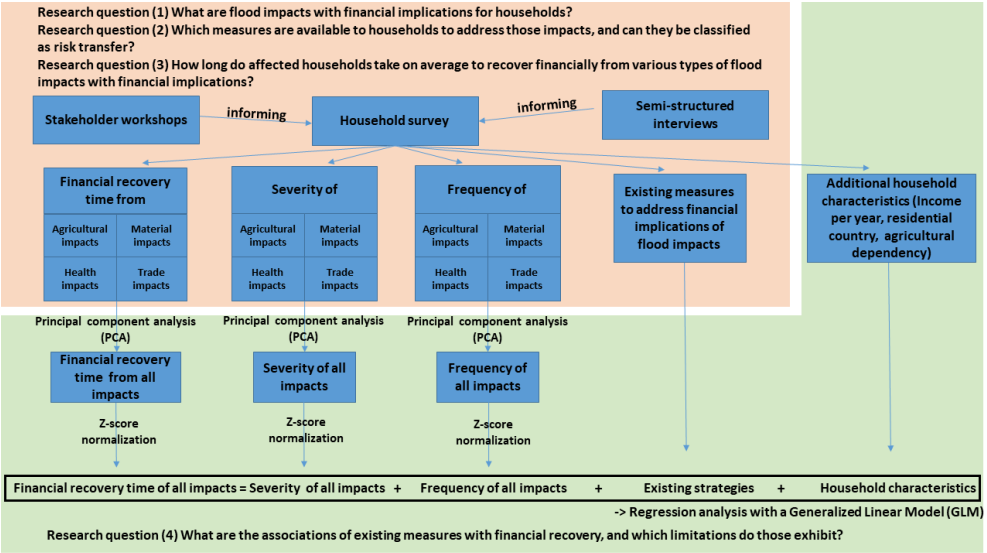


Figure 3.2 Overview of the selection of methods and their relation to the research questions

3.2.3.1 Workshop/Semi-Structured Interviews

The process of data collection began with two virtual stakeholder workshops, inquiring about flood impacts with financial implications and the existing measures to address them. The workshops were held separately in Togo (11 participants) and Benin (14 participants) with participants from ministries, disaster management authorities, volunteer-based organizations, NGOs, Nangbeto Dam/Mono Basin authorities, community mayors, research institutions, and development cooperation institutions. Information was collected on the financial flood impacts prevalent in the research area and the existing mechanisms to deal with them. This information was collected using the online collaboration tools Mentimeter and Miro. In addition, 16 semi-structured interviews were conducted in the research area to complement this data and to prepare the survey data collection. Therefore, residents of flood-affected households were purposively selected to obtain their views on financial flood impacts and the existing ways of transferring these financial risks. We aimed to keep a balanced mixture of female and male interviewees in the semi-structured interviews with village residents.

3.2.3.2 Household Survey

Following these consultations, a household survey was conducted in the LMRB between March 2021 and April 2021. It provided data on the prevalence of flood impacts with financial implications and the existing mechanisms to recover from them across the LMRB in a quantitative manner. The LMRB was surveyed by dividing the research area into flood risk zones of low, medium, and high risk based on elevation data and proximity to the river. Then, 24 villages were selected across these flood-risk zones by considering reports on their flood affectedness (Figure 3.1).

Within the villages, respondent households were selected by taking a censored proportional sample based on the number of households in each village (11.2%). The random selection of households in the villages was made by instructing the interviewers to start at a central landmark and use a random interval and walking direction, until the end of the village was reached (Levy & Lemeshow 2008). A household was interviewed if they were to some extent dependent on agriculture for their livelihood. The required sample size was determined to be 636 by applying a censored proportional sampling approach; this was exceeded, with 744 interviewees. The data collection through the questionnaire was administered on KoboToolBox and carried out together with a team of ten simultaneously deployed field assistants on mobile devices (tablets and mobile phones).

3.2.3.3 Principal Component Analysis

The advantage of a principal component analysis (PCA) is that it is able to reduce dimensionality and still preserve most of the variation in data (Sabharwal & Anjum 2016). Thus, the PCA is applied to the household survey dataset to consolidate the different dimensions of flood impacts with financial implications into one score. This is done to use the PCA score later in regression analysis and avoid the risk of overfitting the regression model (Rothmann 2012). The PCA yields the Eigenvector, the direction of maximum variance in the complete data, and is therefore a suitable way to objectively summarize the data into one parameter (Joliffe & Cadima 2016, Vidal et al. 2016). The PCA is performed separately for the respective indicators, collected in a household survey of flood impact severity, flood impact frequency, and the financial recovery time. As also shown in Figure 3.2, the PCA was applied on three different sets of variables, yielding three scores that summarized (1) the severity of flood impacts for all types of flood impacts, (2) the frequency of flood impacts for all types of flood impacts, and (3) the financial recovery time of households from all types of flood impacts (Annex 12 and Annex 13). The PCA scores were then transformed into z-scores to make them comparable to each other and to enable using them in the same regression model.

3.2.3.4 Generalized Linear Regression Model

Subsequently, a generalized linear regression model (GLM) was applied to the household survey data to research the associations of existing measures with reducing or prolonging the financial recovery time of interviewed households in the LMRB. A GLM was selected over a structural equation model (SEM) because a sample must contain 10–15 events per predictor to avoid overfitting the regression model (Babyak 2004). Thus, the obtained sample size would not have allowed this criterion in the case of an SEM or by considering further interactions between predictors. The model was built as a

combination of predictive and causal modeling (Rothmann 2012). The considered aspect of causal modeling is the selection of variables for the model based on factual logic (Table 3.2, "reason for inclusion"). The considered aspect of predictive modeling was the attention to the significance of the results: the *p*-value.

In the GLM (Table 3.2), the financial recovery time of households was taken as a dependent variable. The following variables were selected as independent variables for the GLM: frequency of all impact types, severity of all impact types, existing strategies to deal with financial flood impacts, household income per year, level of agricultural dependency, and the residence country of the interviewed household (descriptive statistics for main variables in Annex 12). The model aimed to elaborate on which of the existing strategies already play an important role in the financial recovery of a household. The results of the GLM were visualized in a graph format, since it enabled the graphical depiction of the dimension and direction of the results (Kastellec & Leoni 2007). An adjustment to the sampling design was applied in the GLM to make the results proportional to the number of households in the respective villages.

Table 3.2 Model inputs for the GLM

Variables	Unit	Description	Reason for inclusion
Financial recovery time of a household (all impact types, dependent variable)	Months (z-score based on PCA)	Self-reported average period that a household needed over the past 20 years to cover the flood-related expenses after experiencing a flood event	Expression of a household's average financial recovery time
Frequency of reoccurrence (all impact types as PCA score)	Years (z-score based on PCA)	Self-reported average frequency of reoccurrence of flood events over the past 20 years by the household	Accounting for the influence of flood frequency in the recovery time of a household
Severity of reoccurrence (all impact types as PCA score)	Low, Medium, High (z-score based on PCA)	Self-reported average severity of reoccurrence of flood events over the past 20 years by the household	Accounting for the influence of flood severity in the recovery time of a household
Existing strategies: Cooperatives, NGO support, Insurance, Community	Yes, No	Prevalence of existing measures to deal with the financial	Primary measures to address the financial implications of flood impacts

solidarity fund, Dealing with own resources, Governmental support, Credits (bank), Credits (savings groups), Credits (private lender), Remittances (family and friends), None		implications of flood impacts; multiple responses possible	
Level of agricultural dependency of the household	Percentage	Expression of to what degree the income of a household is dependent on agricultural activities	Agriculture is the main livelihood and source of income in the LMRB; the survey sample contains agriculture-dependent households
Household income per year	CFA (z-score)	Self-reported yearly income of the household	This reflects the household's financial capacity to recover financially within their own means
Residential country	Togo, Benin	The country in which a household resides	To account for differences between the two countries of the transboundary basin

3.3 Results

3.3.1 Characteristics and Prevalence of Flood Impacts with Financial Implications on the Household Level in the LMRB

The results of the workshops and semi-structured interviews showed that flood impacts that financially affect households in the LMRB can be categorized into four broader categories (agricultural, material, health, and trade impacts). In the household survey, the interviewed households were also asked to self-report the frequency and severity of the financial impacts from these respective impact categories.

The first category comprised agricultural damages, particularly the loss and destruction of crops and plantations. With the occurrence of a damaging flood, the investment in agricultural work has been in vain. The households must therefore spend money to obtain food for themselves. It was also mentioned that most households primarily cultivate for self-consumption and secondarily for selling

on the market. Therefore, as soon as the flood affects the fields, the households face problems covering their own food consumption properly, which affects their health and necessitates the purchase of food. In addition, they lose out on their invested money in the case they grow crops for the market. The loss of animals (such as poultry, sheep, or pigs) also translates into a loss of financial investment for the household. Agricultural impacts were the most prevalent in the study area, with 96.0% of households having experienced at least some form of such impacts over the last 20 years. In this period, agricultural impacts also happened every year for the majority (59.4%), and for some, even several times a year (18.7%) on average. Regarding the intensity of the impacts, the majority were of severe (56.6%) or medium (35.7%) intensity, while only a few households experienced weak (3.7%) or no agricultural impacts (4.0%). Figure 3.3a illustrates how the severity and frequency of agricultural impacts are interrelated.

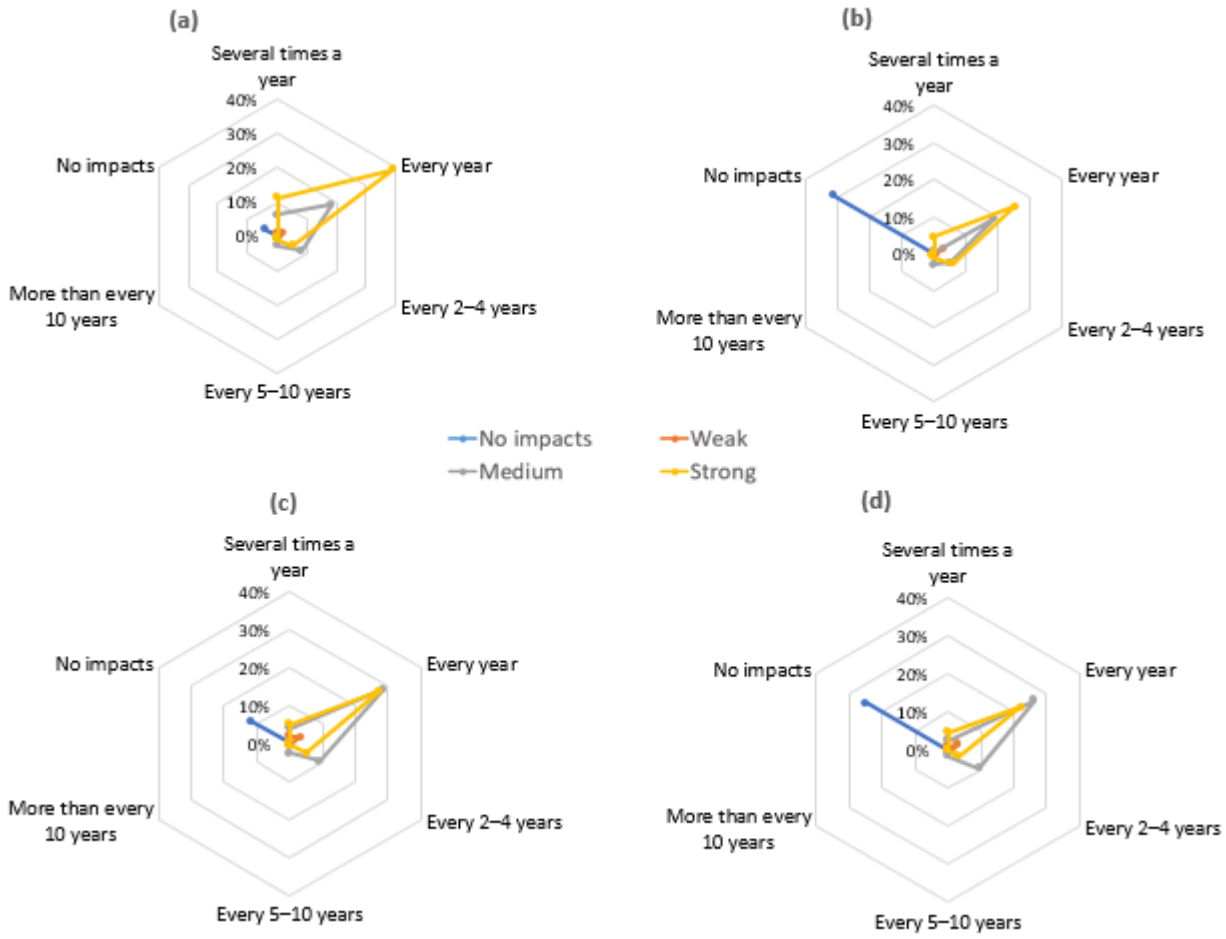


Figure 3.3 Frequency and severity of flood impacts with financial implications as reported in the household surveys (n = 744): (a) agricultural, (b) material, (c) health, and (d) trade impacts

The second category comprised the material damages, particularly the damage or destruction of houses, as a result of flooding. In the case of a damaging flood event, the reconstruction or

reinforcement of the foundation of the house may be necessary, which translates into incurred repair costs for the household by buying cement. Similarly, replacing lost (non-agricultural) personal material belongings and valuables after an impactful flood event is associated with costs. In the past 20 years, 68.8% of the interviewed households experienced some form of material impact within the study area. In this period, material impacts happened every year for a large share of households (46.7%) and every two to four years for some (11.4%) on average. The average severity of the material impacts over the last 20 years was severe (37.3%) or medium (27.4%) for most households. However, around a third of interviewed households did not experience material impacts (31.2%), while a minority experienced weak impacts (4.1%) on average. Figure 3.3b illustrates how the severity and frequency of material impacts are interrelated.

Thirdly, floods were mentioned to affect the health of household members by raising the likelihood of falling ill with malaria, diarrhea, or sore feet by walking through the flood waters, particularly for children. The subsequent payments for medical care or medication translate into a cost for the household. Health impacts were a widely prevalent category of flood impacts with financial implications, with 88.3% of interviewed households experiencing at least some form of such impacts over the past 20 years. A large share experienced these impacts every year (59.5%), some even several times a year (10.7%), while another share experienced them every two to four years (14.6%). The average severity of the health impacts was strong (38.1%) and medium (44.5%) for the interviewed households, while 5.7% experienced weak impacts. Figure 3.3c illustrates how the severity and frequency of health impacts are interrelated.

Finally, floods affect the trade activity of a household due to the damaging of stored agricultural or other manufactured products. Households also encounter difficulties of transporting the goods to the market due to inundated or damaged roads or even affected marketplaces. Thus, these types of impacts lead to lost income that would be generated otherwise. Impacts on trade were experienced by 75.1% of interviewed households over the last 20 years. A major share (51.6%) of interviewed households experienced impacts on trade activities once a year, on average, to at least some degree. Another share (13.4%) experienced them every two to four years, while only 1.7% experienced them every five to ten years. Regarding the severity of the events, the largest share of households experienced these impacts with strong (30.2%) and medium (39.7%) severity. In comparison, only 5.2% experienced them in weak severity. Figure 3.3d illustrates how the severity and frequency of trade impacts are interrelated.

3.3.2 Financial Coping Strategies

This study yielded categories of options among the population at risk to deal with the previously outlined flood impacts with financial implications (Figure 3.4). Respondents were able to select multiple responses regarding the options usually available to them. The existing practices are divided into risk transfer, emergency response, risk retention, and external sources of financing.

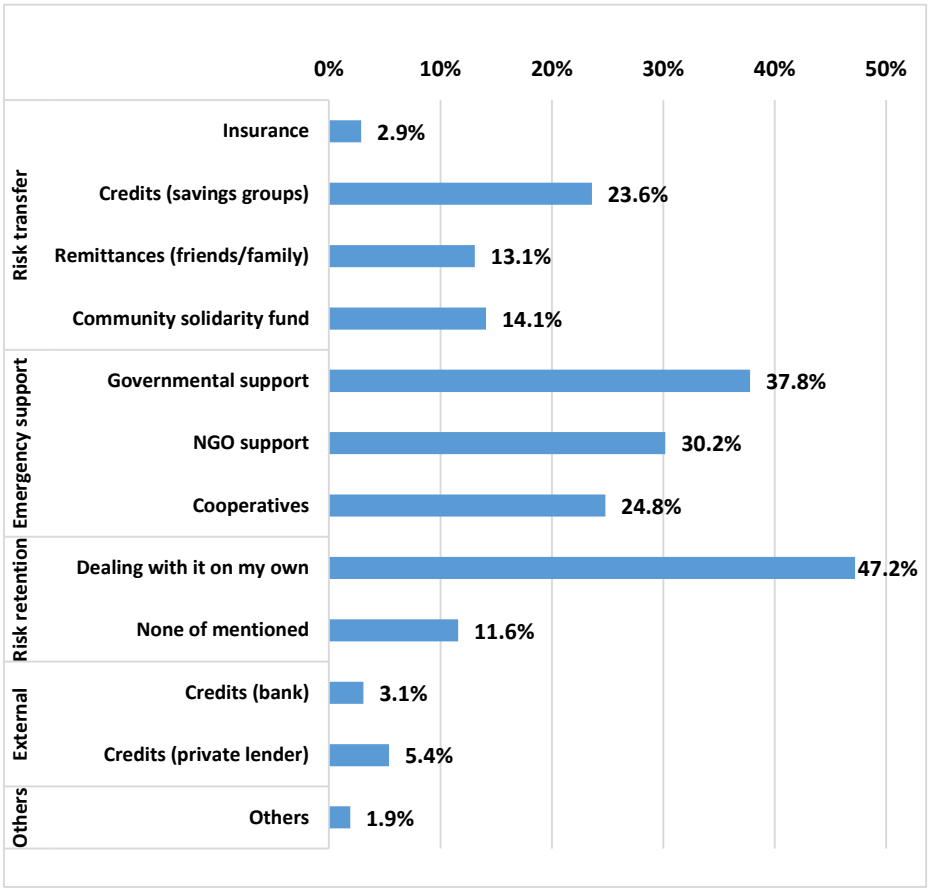


Figure 3.4 Existing options at the household level to deal with flood impacts containing financial implications as reported in the household survey (multiple responses possible; n = 744)

Firstly, based on Table 3.1, some existing measures were identified as risk transfer, both formal and informal. As a formal example of risk transfer, insurance (2.9%) can be mentioned, since it has a legal framework that explicitly regulates its business. The low prevalence of insurance illustrates the currently minor role of formal risk transfer mechanisms in addressing the financial impacts of floods in the LMRB. Concerning informal risk transfer mechanisms, credits from savings groups (roundtable savings groups/tontines/clubs de mères) frequently were mentioned (23.6%). However, these groups are usually not formed with the objective to provide assistance in times of flooding. Instead, their aim is to save for investments of their members in the private domain (e.g., education, construction, purchases). In some emergency cases, it is possible for households to obtain credits from such groups,

though they usually have to be paid back within a few months. This aspect is underscored by 58.4% of interviewed households being members of savings groups in general; however, only 23.6% were able to receive some form of financial assistance after experiencing a harmful flood event, leading to incurring expenses. Still, due to the aspects of pooling financial resources, mutual exchanges, and leniency in times of being flood-affected, it is perceived as a form of risk transfer in this study. Likewise, community solidarity funds (14.1%) were reported to exist in some villages to support cultural activities or funerals of community members. In some cases of having disproportionally highly affected community members, a few of them were able to receive some form of financial assistance from the fund. Thus, these funds can be seen as risk transfer in this study because they act as a form of risk pool on the village level based on mutual exchanges that financially support flood-affected village members under certain circumstances, despite not being formed for that purpose. Moreover, remittances from family or friends (13.1%) appeared as another form of informal risk transfer, though at a lower frequency. This is categorized as risk transfer in this study because these transactions are mostly informal expectations between family members or friends of assistance in times of need, with the aspiration of being reciprocal.

Furthermore, another group of existing measures that could be observed as mitigating the financial implications of flood impact in the LMRB was classified as emergency assistance. Prevalent measures from that category were the support from governmental actors (37.8%) and NGOs (30.2%). These two measures were not classified as risk transfer due to the fact that they do not contain the aspect of beneficiaries exchanging benefits to the party that provides coverage. In some cases, the support came in the form of cash transfer, while in others, it did not but entailed the provision of food, shelter, or medication as emergency response. In any case, this assistance was taken into account in this study since it avoided, or compensated for, potential financial expenses of households. Moreover, a further prevalent type of emergency assistance came in cooperatives (24.8%). In the study area, cooperatives were understood as groups of farmers who organize themselves for mutual help to work in the field or in fishing. Generally, cooperatives are not formed to provide assistance in times of flooding. However, in some cases, members assist each other in rescuing material goods in anticipation of a flood and in the restoration process of the agricultural activities after a flood, which is usually associated with financial expenses. As a consequence, cooperatives were not classified as risk transfer because they do not directly involve the provision of financial support and are not formed with the intent of providing support in times of flooding, yet they do so due to the absence of other measures.

A very prevalent category of measures to address the financial implications of flood impacts can be seen as risk retention. In the household survey, the most frequent response of interviewed households

was to deal with the financial implications of flood impacts using their own means (47.2%). This option comprised using one's own savings, selling material belongings, or resorting to generate alternative forms of income. It is also worth noting that 11.6% indicated not having any means, not even their own, to deal with the financial implications of flood impacts. Other external and less prevalent sources of credit that go beyond the networks of family or community were credits from a private lender (5.4%) and credits from formal providers such as banks (finance institutions) (3.1%).

3.3.3 Financial Recovery Times of Households from Flood Impacts

Another aspect researched in the household survey was the time that households needed on average to recover financially from the four types of impacts identified as having financial implications (agricultural, material, health, trade; Figure 3.5). Recovery was defined as the moment at which households perceived themselves as having recovered the financial expenses that they incurred through the impacts of the flood. Regarding agricultural impacts, around 70% recovered within one year or less or did not experience such impacts. In contrast, around 80% of the households recovered within one year for the other three types of impacts. Moreover, shares of households take on average longer than one year to recover (11.14% for agricultural; 12.15% for material; 10.95% for health; and 10.8% for trade impacts). In addition, it is important to mention that some households indicated that they usually do not recover from the financial implications of flood events that they experience (16.95% for agricultural; 8.94% for material; 7.57% for health; and 8.08% for trade impacts).

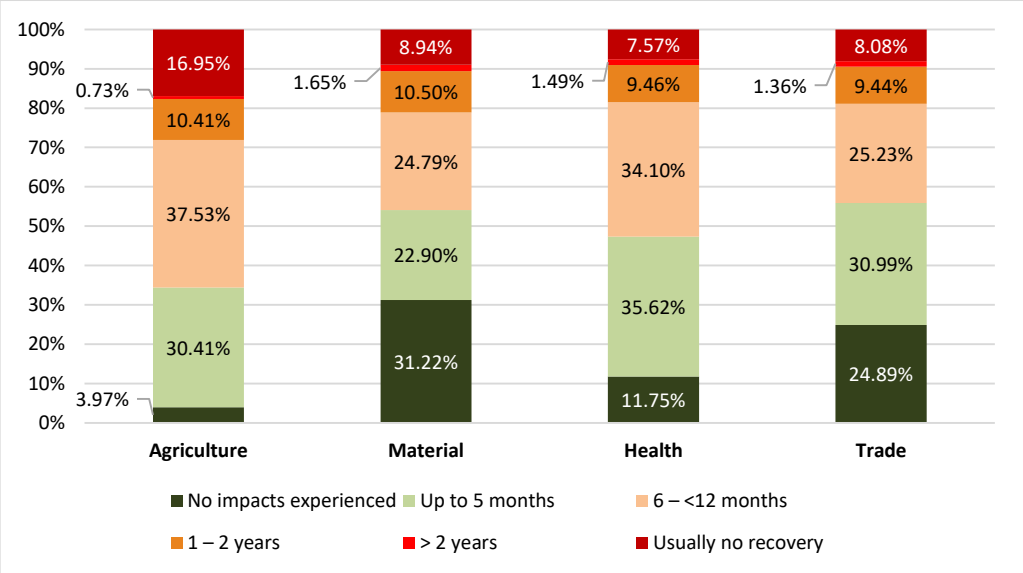


Figure 3.5 Average financial recovery time of households from flood impacts with financial implications by impact category as reported in the household surveys (n = 744)

3.3.4 Limitations of Existing Financial Coping Strategies

In order to address the associations of existing measures with financial recovery, and the limitations they exhibit, a regression analysis with a generalized linear model (GLM) was performed (Table 3.3). The R-squared value of the GLM amounted to 0.2700, portraying a strong value of explanatory power for the variance in financial recovery time.

The results of the regression analysis (Figure 3.6) illustrated the influence of the frequency and severity of (Section 3.1) and the existing strategies to deal with (Section 3.2) flood impacts with financial implications on shortening or prolonging the financial recovery time. Additionally, the influence of factors such as the level of household income, residence country, and the level of agricultural dependency was tested. If the coefficient is a positive value, the presence of the variable is associated with a household taking longer to recover financially. If the coefficient is a negative value, the presence of the variable is associated with a household taking less time to recover financially. The findings are statistically significant for all variables whose *p*-values are below 0.05 (if the blue and red lines in Figure 3.6 do not intersect). The detailed GLM results can also be found in Table 3.3.

The analysis revealed significant influences of the following variables. Firstly, the aggregated severity of all four types of flood impacts with financial implications had a strong and highly significant association with a prolongation of the financial recovery time, which is an intuitive finding. However, this could not be found for the aggregated frequency of all four types of flood impacts with financial implications. Secondly, it was shown that the household income per year is slightly yet significantly associated with a prolongation of the financial recovery time. Thirdly, it was found that residing in Togo is significantly associated with a prolongation of the financial recovery time of households. Moreover, it was shown that the level of agricultural dependency is slightly yet significantly associated with a decrease in households' financial recovery time. Regarding the influence of the existing strategies (outlined in Section 3.2.), it became apparent that both cooperatives and credits from savings groups have a strong and highly significant association with a shortened financial recovery time of households. Interestingly, NGO support was associated with a strong and highly significant prolongation of financial recovery time. However, this observation could be explained by NGOs mostly focusing their work on highly flood-affected people. Finally, cases where no means were available to a household were significantly associated with a longer financial recovery time, which is an intuitive finding.

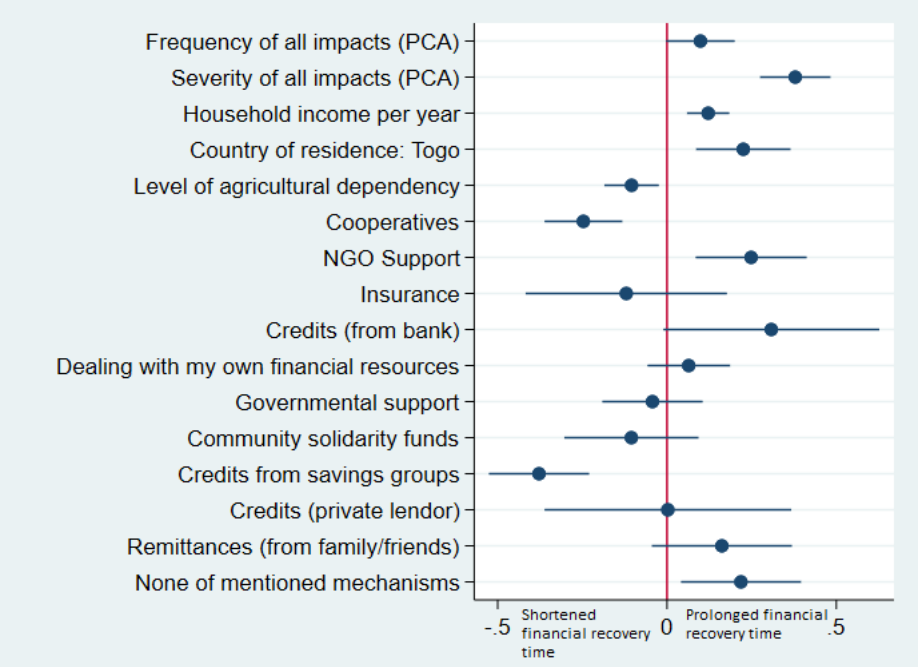


Figure 3.6 Association of factors with financial recovery time from flood impacts (GLM results)

Table 3.3 GLM results

Generalized Linear Model (GLM)

Survey: Linear regression

Number of strata = 24

Number of obs = 724

Number of PSUs = 724

Population size = 6920.6052

Design df = 700

F(16, 685) = 25.89

Prob > F = 0.0000

R-squared = 0.2700

Linearized **Dependent: Financial Recovery Time (All Impact Types)**	**Coefficient**	**Std. Error**	***p*-Value**	**(95% Conf. Interval)**	
Frequency (all flood impacts types)	0.0986015	0.0517094	0.057	−0.0029225	0.2001255
Severity (all flood impacts types)	0.3786982	0.0529141	0.000 ***	0.2748089	0.4825876
HH income per year	0.1215589	0.0318714	0.000 ***	0.0589838	0.1841339
Residence Country: Togo	0.2253541	0.0709726	0.002 ***	0.0860094	0.3646987
Level of HH's agricultural dependency	−0.1045096	0.0409899	0.011 ***	−0.1849874	−0.0240317
Cooperatives	−0.2469127	0.0584784	0.000 ***	−0.3617267	−0.1320987
NGO support	0.2484345	0.0835508	0.003 ***	0.0843943	0.4124746
Insurance	−0.1202624	0.1514003	0.427	−0.4175156	0.1769907
Credits (from a bank)	0.307972	0.1623919	0.058	−0.0108615	0.6268054
Using my own resources	0.0641535	0.062116	0.302	−0.0578025	0.1861095
Governmental Support	−0.0429331	0.0755487	0.570	−0.1912623	0.1053961
Community Solidarity Funds	−0.1051181	0.1008933	0.298	−0.3032078	0.0929715
Credits (from savings groups)	−0.3779169	0.0754657	0.000 ***	−0.5260831	−0.2297508
Credits (from a private lender)	0.0024999	0.185543	0.989	−0.3617875	0.3667874
Remittances (from friend or family)	0.1620053	0.1053559	0.125	−0.0448462	0.3688568
None of the abovementioned options	0.2183191	0.0902753	0.016 ***	0.0410762	0.395562

*** significance level $p < 0.05$.

No statistically significant results could be produced for insurance, using one's own resources, governmental support, community solidarity funds, credits from a private lender, credits from banks, and remittances from family or friends. However, it is also possible that the observed associations of existing measures with a shortened or prolonged financial recovery time are due to predominantly being drawn upon in times of high or low flood severity, respectively (e.g., credits from savings

groups/cooperatives in times of low frequency/severity or NGO support in times of high frequency/severity; see Annex 14 for separate GLMs assessing the individual relationship between flood impact frequency and severity with the remaining independent variables).

3.4 Discussion

The reported frequency and severity of flood impacts with financial implications that the study found in the LMRB can be seen as too high to be suitable for creating a flood insurance mechanism without further efforts in flood risk reduction. Consequently, a large share of the population at risk in the LMRB would not be able to afford an insurance mechanism. This is due to the fact that this area experiences flood impacts every year or, in some cases, several times a year; thus, residents would potentially be charged high premiums (Radermacher 2006). Under such conditions, flood insurance would not be economically attractive for insurance companies either. Consequently, concerted adaptation efforts are needed to substantially reduce the recurrence period of flood impacts for the majority of the basin population to better fulfill the conditions of insurability (Radermacher 2006). This is also envisaged in risk layering approaches that recommend applying adaptation measures in the case of damages frequently appearing (Cissé 2021, Cissé et al. 2021). Risk transfer approaches are well suited for low-frequency, high-impact events but not for events that occur in high frequency (Schäfer et al. 2016).

Furthermore, the study found that the existing options to deal with the financial implications of flood impacts rather seldomly take the shape of risk transfer. The most common strategies in LMRB are private risk retention and emergency relief from governmental actors or NGOs. This finding is in agreement with Hallegatte et al. (2016), who stated that poorer households often only have access to social protection mechanisms, such as government assistance and NGO support, in times of a disaster with larger severity. In comparison, richer households can better access formal mechanisms such as insurance (Hallegatte et al. 2016). In essence, the results show that, currently, there are no mechanisms in place that are explicitly designed to alleviate the financial implications of flood impacts in the LMRB. It appears as if locally led development initiatives (cooperatives, savings groups, solidarity funds and, in particular, private financial resources) have to serve as means of financial coping in times of experiencing flood impacts, which they were not originally designated for. It can also be assumed that the high percentage of households using their own financial resources can be explained by a lack of other options rather than choosing this route. As a consequence, at the household and community level in the LMRB, many are constrained in their financial achievements in the event of a harmful flood event because they must use resources that were not intended for such a purpose. This point is further

illustrated by those interviewed households indicating that they took longer than one year to recover or never recovered from the financial implications of flood impacts. In a context in which floods have become a yearly occurrence, this situation is not sustainable. Such flood impacts are bound to repeatedly erode their ability to cope with the impacts over time.

In addition, the study found that if a household was able to access support from a cooperative or receive a credit from a savings group, it was also strongly associated with a shorter financial recovery time. The latter finding corroborates the result of Panman et al. (2021), who showed that flood-affected households in Dar es Salaam that had at least one member in a savings group recovered faster than non-members. Moreover, access to credits from savings groups increased only marginally across income groups in this study. The finding is interesting with regard to Hallegatte et al. (2016), who stated that savings or credit is often not an option for poorer households. Nevertheless, the local structure of the mechanism seems to enable broader access and flexibility, albeit entailing smaller amounts than from conventional credit providers. More qualitative research is needed to explore the ways and criteria under which such support takes place in cooperatives and savings groups, since only a third of the households that were members in savings groups could access some kind of financial assistance in times of flooding. It should be pointed out that savings groups and cooperatives were not set up to provide assistance to their members in times of flooding in the research area. However, they should be of high interest in the case of designing a formal risk transfer mechanism to act as potential components of a scheme and even be engaged in prevention and awareness-raising activities, as also suggested by Panman et al. (2021). In addition, even in established flood insurance systems such as the National Flood Insurance Programme (NFIP; USA), the role of continuous awareness-raising for risk is seen as crucial to keep people engaged in actively subscribing to the program over time (Kousky et al. 2020). It could be worth exploring how a potential formal insurance product would act as a replacement or complementary mechanism to existing informal practices of risk sharing (Berg et al. 2022, Will et al. 2021). The role of mobile payment technology in informal risk sharing (Riley 2018) could be of importance in this context as well. In addition, it could be of relevance to conduct such a study in a comparative manner between urban and rural contexts, regarding potential differences in disaster vulnerability (Quesada-Román et al. 2022).

This study presents some limitations. Firstly, the four identified categories of flood impacts with financial implications might be the most prevalent ones that were found in the LMRB. However, it cannot be ruled out that there are further ways in which flood impacts cause a financial need in a household (such as the cost of ecosystem-related losses/environmental degradation), given the diversity of flood impacts in the West African region (Wagner et al. 2021). Furthermore, this study

bears the limitation of working with self-reported data from flood-affected households on flood frequency and severity as well as the respective impacts. Therefore, care has to be taken when interpreting the data, as the data might slightly differ from data from more objective sources due to potential perception bias. However, this approach was necessary to be able to explore the topic in the area due to the absence of other hydrological databases or disaster impact inventories. In addition, this study bears the limitation of potentially overlooking unknown confounders in the GLM as well as only showing plausible but not causal relationships due to being an observational study. Another useful angle of approaching the topic would have been to perform a panel study in which the same households were interviewed at several points in time. In that way, the long-term effect of certain coping strategies on financial well-being could have been better assessed.

Future research in the LMRB also needs to generate reliable recommendations for adaptation measures while keeping in mind the level of acceptance of those measures among the population at risk. If effective adaptation measures are implemented and insurance is pursued subsequently at some point, it will be essential to explore the understanding, trust, and willingness to buy a potential product among the population regarding such schemes due to the low level of previous exposure to insurance. In addition, several methods to increase coverage could be drawn upon from the NFIP context, such as opt-out designs, mandatory offers, community policies, and low-income voucher programs [90]. Furthermore, another aspect to be considered and drawn upon from the NFIP is to consider the ways in which a potential insurance mechanism has redistributional effects in making lower-income households receive a larger share of the payouts (Bin et al. 2017). However, it will also be crucial to learn from factors of success and failure from other microinsurance schemes targeting low-income earners and to carefully balance the components of a potential scheme in terms of humanitarian intervention and business venture (Yore & Walker 2019). Moreover, the findings of this study could impact disaster databases such as EM-Dat in terms of collecting impact data in a more encompassing way that goes beyond direct damages (EM-Dat 2021). The financial burdens on a household level arising from a disaster could be considered. However, a consensus for a standardized methodology for post-disaster needs assessments would be required to generate the required data. Thus, further research will be needed to provide additional empirical insights to enrich the perspective gained from this study.

3.5 Conclusions

This study shows that flood impacts have diverse financial implications, and innovative risk transfer approaches are required to address them. However, as current levels of impact frequency and severity

show, effective adaptation measures are necessary for the LMRB to fulfill insurability criteria. In addition, there are currently no formal risk transfer mechanisms in place in the LMRB that were set up to help in times of flooding. In the absence of other mechanisms, locally led development initiatives (cooperatives, savings groups, community solidarity funds) have to step in even though they were not formed for that purpose. This situation erodes the financial achievements of the affected population and prevents them from recovering financially from flood impacts. While the current recurrence period of flood damages does not favor the direct implementation of an insurance mechanism, the setting up of an appropriate risk transfer instrument, adapted to the local context and involving established local actors, is necessary for the long term. Therefore, the role of cooperatives and savings groups in the financial recovery process should be explored further. These groups appear to be relevant actors closely aligned to the local population, and they can be potentially integrated into an innovative insurance/risk transfer scheme. Such approaches could address the residual risk that remains after the implementation of effective adaptation measures that manage to reduce the reoccurrence period of flood impacts. To achieve progress in this area, this study finishes with a strong recommendation for further research in the areas of generating reliable recommendations for adaptation measures and exploring the level of interest of the population regarding potential insurance schemes and the trust of and experience with such products. Research on the latter aspects will shed more light on the suitability of insurance in a "smart mix" of adaptation measures from a different perspective.

3.6 References

African Development Bank (1995) Benin/Togo Nangbeto Hydroelectric Dam Project Performance Evaluation Report (PPER). Available online: https://www.afdb.org/en/documents/document/multinational-nangbeto-hydroelectric-dam-benin-togo-9679 (accessed on 10 June 2021).

Afriyie, K.; Ganle, J.K.; Santos, E. (2018) 'The floods came and we lost everything': Weather extremes and households' asset vulnerability and adaptation in rural Ghana. *Clim. Dev. 10*, 259–274. https://doi.org/10.1080/17565529.2017.1291403.

Agbédoufio, P. (2020) Risques des Catastrophes dans le Mono: Lokossa en État D'alerte. Available online: https://matinlibre.com/2020/09/04/risques-des-catastrophes-dans-le-mono-lokossa-en-etat-dalerte/ (accessed on 10 June 2021).

Agence Bénin Presse (2021) Environnement/Près de 70,000 Populations Affectées Par L'inondation du Fleuve Mono Dans les Communes D'ATHIÉMÉ et de Grand-Popo Selon la PDRRC-ACC. Available online: https://www.agencebeninpresse.info/web/depeche/63/pres-de-70-000-populations-affectees-par-l-inondation-du-fleuve-mono-dans-les-communes-d-athieme-et-de-grand-popo-selon-la-pdrrc (accessed on 10 July 2021).

Aich, V.; Koné, B.; Hattermann, F.; Paton, E. (2016) Time Series Analysis of Floods across the Niger River Basin. *Water 8*, 165. https://doi.org/10.3390/w8040165.

Ajibade, I.; McBean, G.; Bezner-Kerr, R. (2013) Urban flooding in Lagos, Nigeria: Patterns of vulnerability and resilience among women. *Glob. Environ. Chang. 23*, 1714–1725. https://doi.org/10.1016/j.gloenvcha.2013.08.009.

Amoussou, E.; Awoye, H.; Totin Vodounon, H.S.; Obahoundje, S.; Camberlin, P.; Diedhiou, A.; Kouadio, K.; Mahé, G.; Houndénou, C.; Boko, M. (2020) Climate and Extreme Rainfall Events in the Mono River Basin (West Africa): Investigating Future Changes with Regional Climate Models. *Water 12*, 833. https://doi.org/10.3390/w12030833.

Amoussou, E.; Tramblay, Y.; Totin, H.S.; Mahé, G.; Camberlin, P. (2014) Dynamique et modélisation des crues dans le bassin du Mono à Nangbéto (Togo/Bénin). *Hydrol. Sci. J. 59*, 2060–2071. https://doi.org/10.1080/02626667.2013.871015.

Asenso Barnieh, B.; Li Jia; Menenti, M.; Zhou, J.; Zeng, Y. (2020) Mapping Land Use Land Cover Transitions at Different Spatiotemporal Scales in West Africa. *Sustainability 12*, 8565. https://doi.org/10.3390/su12208565.

Babyak, M.A. (2004) What You See May Not Be What You Get: A Brief, Nontechnical Introduction to Overfitting in Regression-Type Models. *Psychosom. Med. 66*, 411–421.

Badou, F.D.; Hounkpè, J.; Yira, Y.; Ibrahim, M.; Bossa, A.Y. (2019) Increasing devastating flood events in West Africa: Who is to blame? In *Regional Climate Change Series: Floods*; Adegoke, J., Sylla, M.B., Bossa, A.Y., Ogunjobi, K., Adounkpe, J., Ed.; WASCAL Publishing: Accra, Ghana; pp 84–90.

Berg, E.; Blake, M.; Morsink, K. (2022) Risk sharing and the demand for insurance: Theory and experimental evidence from Ethiopia. *J. Econ. Behav. Organ. 195*, 236–256. https://doi.org/10.1016/j.jebo.2021.12.035.

Bin, O.; Bishop, J.; Kousky, C. (2017) Does the National Flood Insurance Program Have Redistributional Effects? *B.E. J. Econ. Anal. Policy 17*. pp. 20160321. https://doi.org/10.1515/bejeap-2016-0321.

Bouwer, L.M. (2019) Observed and Projected Impacts from Extreme Weather Events: Implications for Loss and Damage. In *Loss and Damage from Climate Change: Concepts, Methods and Policy Options, Climate Risk Management, Policy and Governance*; Mechler, R., Bouwer, L.M., Schinko, T., Surminski, S., Linnerooth-Bayer, J., Eds.; Springer: Cham, Switzerland; pp. 63–82.

Christophers, B. (2019) The allusive market: Insurance of flood risk in neoliberal Britain. *Econ. Soc. 48*, 1–29. https://doi.org/10.1080/03085147.2018.1547494.

Cissé, J.D. (2021) *Climate and Disaster Risk Financing Instruments: An Overview*; United Nations University Institute for Environment and Human Security: Bonn, Germany, 2021. Available online: https://climate-insurance.org/wp-content/uploads/2021/05/Climate-and-Disaster-Risk-Financing-Instruments.pdf (accessed on 30 January 2022).

Cissé, J.D.; Kreft, S.; Toepper, J.; Stadtmueller, D. (2021) *From Innovation to Learning: A Strategic Evidence Roadmap for Climate and Disaster Risk Finance and Insurance*; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: Bonn/Eschborn, Germany. Available online: https://climate-insurance.org/wp-content/uploads/2021/10/Strategic-CDRFI-Evidence-Roadmap.pdf (accessed on 17 March 2022).

Deutsche Klimafinanzierung (2021) Die InsuResilience Initiative und Global Partnership. Available online: https://www.deutscheklimafinanzierung.de/instrument/insuresilience/ (accessed on 15 November 2021).

EM-Dat (2021) The Emergency Events Database—Universite Catholique de Louvain (UCL). Available online: https://public.emdat.be/ (accessed on 28 September 2021).

Floodlist (2019) Togo and Benin—Mono River Flooding Affects 50,000. Available online: https://floodlist.com/africa/togo-benin-mono-river-floods-october-november-2019 (accessed on 30 September 2021).

Floodlist (2020a) Togo—Thousands Affected by Oti River Floods in North. Available online: https://floodlist.com/africa/togo-oti-river-floods-october-2020 (accessed on 30 September 2021).

Floodlist (2020b) West Africa—Floods Hit Burkina Faso and Northern Ghana. Available online: https://floodlist.com/africa/west-africa-burkinafaso-ghana-september-2020 (accessed on 30 September 2021).

Floodlist (2020c) West Africa—More Floods in Niger, Death Toll Rises in Burkina Faso. Available online: https://floodlist.com/africa/floods-niger-burkinafaso-september-2020 (accessed on 30 September 2021).

Germanwatch & MCII. (2020) Climate Risk Insurance and Informal Risk-Sharing: A Critical Literature Appraisal. Available online: https://climate-insurance.org/wp-content/uploads/2020/05/Climate_risk_insurance_and_ISRA_Discussion_Paper_No_4_FINAL-2.pdf (accessed on 30 September 2021).

Granados-Bolaños, S.; Quesada-Román, A.; Alvarado, G.E. (2021) Low-cost UAV applications in dynamic tropical volcanic landforms. *J. Volcanol. Geotherm. Res. 410*, 107143. https://doi.org/10.1016/j.jvolgeores.2020.107143.

Güneralp, B.; Güneralp, İ.; Liu, Y. (2015) Changing global patterns of urban exposure to flood and drought hazards. *Glob. Environ. Chang. 31*, 217–225. https://doi.org/10.1016/j.gloenvcha.2015.01.002.

Haer, T.; Botzen, W.J.W.; Aerts, J.C.J.H. (2019) Advancing disaster policies by integrating dynamic adaptive behaviour in risk assessments using an agent-based modelling approach. *Environ. Res. Lett. 14*, 44022. https://doi.org/10.1088/1748-9326/ab0770.

Hallegatte, S.; Bangalore, M.; Bonzanigo, L.; Fay, M.; Kane, T.; Narloch, U.; Rozenberg, J.; Treguer, D.; Vogt-Schilb, A. (2016) *Shock Waves*: *Managing the Impacts of Climate Change on Poverty*; World Bank Publications: Washington, DC, USA. Available online: https://documents1.worldbank.org/curated/en/260011486755946625/pdf/ShockWaves-FullReport.pdf (accessed on 24 January 2022).

Hochrainer-Stigler, S.; Linnerooth-Bayer, J.; Lorant, A. (2017) The European Union Solidarity Fund: An assessment of its recent reforms. *Mitig. Adapt. Strateg. Glob. Chang. 22*, 547–563. https://doi.org/10.1007/s11027-015-9687-3.

Hounguè, N.R.; Ogbu, K.N.; Almoradie, A.D.S.; Evers, M. (2021) Evaluation of the performance of remotely sensed rainfall datasets for flood simulation in the transboundary Mono River catchment, Togo and Benin. *J. Hydrol. Reg. Stud. 36*, 100875. https://doi.org/10.1016/j.ejrh.2021.100875.

Hounkpêvi, A.F. (2019) URGENT—Débordement du Fleuve Mono: 15 Villages Sous L'eau à Athiémé. Available online: http://lautrefigaro.over-blog.com/2019/10/urgent-debordement-du-fleuve-mono-15-villages-sous-l-eau-a-athieme.html (accessed on 10 May 2021).

InsuResilience Global Partnership (2021) InsuResilience Global Partnership Vision 2025. Available online: https://www.insuresilience.org/wp-content/uploads/2021/11/vision2025_211022.pdf (accessed on 15 November 2021).

Islam, A.; Leister, C.M.; Mahmud, M.; Raschky, P.A. (2020) Natural disaster and risk-sharing behavior: Evidence from rural Bangladesh. *J. Risk Uncertain 61*, 67–99. https://doi.org/10.1007/s11166-020-09334-5.

Jolliffe, I.T.; Cadima, J. (2016) Principal component analysis: A review and recent developments. *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci. 374*, 20150202. https://doi.org/10.1098/rsta.2015.0202.

Jongman, B.; Hochrainer-Stigler, S.; Feyen, L.; Aerts, J.C.J.H.; Mechler, R.; Botzen, W.J.W.; Bouwer, L.M.; Pflug, G.; Rojas, R.; Ward, P.J. (2014) Increasing stress on disaster-risk finance due to large floods. *Nat. Clim. Chang. 4*, 264–268. https://doi.org/10.1038/NCLIMATE2124.

Kastellec, J.P.; Leoni, E.L. (2007) Using Graphs Instead of Tables in Political Science. *Perspect. Politics 5*, 755–771. https://doi.org/10.1017/S1537592707072209.

Kheradmand, S.; Seidou, O.; Konte, D.; Barmou Batoure, M.B. (2018) Evaluation of adaptation options to flood risk in a probabilistic framework. *J. Hydrol. Reg. Stud. 19*, 1–16. https://doi.org/10.1016/j.ejrh.2018.07.001.

Kissi, A.E.; Abbey, G.A.; Agboka, K.; Egbendewe, A. (2015) Quantitative Assessment of Vulnerability to Flood Hazards in Downstream Area of Mono Basin, South-Eastern Togo: Yoto District. *J. Geogr. Inf. Syst. 7*, 607–619. https://doi.org/10.4236/jgis.2015.76049.

Komi, K.; Amisigo, B.; Diekkrüger, B. (2016) Integrated Flood Risk Assessment of Rural Communities in the Oti River Basin, West Africa. *Hydrology 3*, 42. https://doi.org/10.3390/hydrology3040042.

Komi, K.; Amisigo, B.; Diekkrüger, B.; Hountondji, F. (2016) Regional Flood Frequency Analysis in the Volta River Basin, West Africa. *Hydrology 3*, 5. https://doi.org/10.3390/hydrology3010005.

Kousky, C.; Shabman, L.; Linder-Baptie, Z.; St. Peter, E. (2020) *Perspectives on Flood Insurance Demand Outside the 100-Year Floodplain*; Issue Brief; Wharton University of Pennsylvania: Philadelphia, PA, USA. Available online: https://riskcenter.wharton.upenn.edu/wp-content/uploads/2020/05/Perspectives-on-Flood-Insurance-Demand-Outside-the-100-Year-Floodplain.pdf (accessed on 21 June 2022).

Kousky, C.; Lingle, B.; Kunreuther, H.; Shabman, L. (2019) *Moving the Needle on Closing the Flood Insurance Gap*; Wharton University of Pennsylvania: Philadelphia, PA, USA, 2019. Available online: https://riskcenter.wharton.upenn.edu/wp-content/uploads/2019/02/Moving-the-Needle-on-Closing-the-Flood-Insurance-Gap.pdf (accessed on 21 June 2022).

Kron, W.; Eichner, J.; Kundzewicz, Z.W. (2019) Reduction of flood risk in Europe—Reflections from a reinsurance perspective. *J. Hydrol. 576*, 197–209. https://doi.org/10.1016/j.jhydrol.2019.06.050

Mai, T.; Mushtaq, S.; Reardon-Smith, K.; Webb, P.; Stone, R.; Kath, J.; An-Vo, D.-A. (2020) Defining flood risk management strategies: A systems approach. *Int. J. Disaster Risk Reduct. 47*, 101550. https://doi.org/10.1016/j.ijdrr.2020.101550.

Masson-Delmotte, V.; P. Zhai; A. Pirani; S. L. Connors; C. Péan; S. Berger; N. Caud; Y. Chen; L. Goldfarb; M. I. Gomis; et al. (2021) Summary for Policymakers. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; IPCC, Ed.; Cambridge University Press: Cambridge, UK.

Meton, A. (2019) Gestion des Risques et Catastrophes: L'assurance Comme une Priorité, Selon le Professeur Théodore Adjakpa. Available online: https://lanation.bj/gestion-des-risques-et-catastrophes-lassurance-comme-une-priorite-selon-le-professeur-theodore-adjakpa/ (accessed on 10 June 2021).

Mike, M. (2021) Crue du Fleuve Mono: Probables Lâchées D'eau Depuis Nangbéto. Available online: https://matinlibre.com/2021/08/31/crue-du-fleuve-mono-probables-lachees-deau-depuis-nangbeto/ (accessed on 10 July 2021).

Nato, G. (2021) Risques de Catastrophe Liés aux Inondations dans le Mono: L'Anpc Alerte et Sensibilise la Plateforme de Lokossa. Available online: https://actubenin.com/risques-de-catastrophe-lies-aux-inondations-dans-le-monolanpc-alerte-et-sensibilise-la-plateforme-de-lokossa (accessed on 10 July 2021).

Ntajal, J.; Lamptey, B.L.; Mahamadou, I.B.; Nyarko, B.K. (2017) Flood disaster risk mapping in the Lower Mono River Basin in Togo, West Africa. *Int. J. Disaster Risk Reduct. 23*, 93–103. https://doi.org/10.1016/j.ijdrr.2017.03.015.

Ntajal, J.; Lamptey, B.L.; Mianikpo Sogbedjic, J.; Kpotivid, W.-B.K. (2016) Rainfall trends ad flood frequency analyses in the Lower Mono River Basin in Togo, West Africa. *Int. J. Adv. Res. 4*, 2320–9186.

Levy, P.S.; Lemeshow, S. (2008) *Sampling of Populations*: *Methods and Applications*, 4th ed.; John Wiley & Sons, Inc: Hoboken, NJ, USA; ISBN 0470374594.

Livelihood Centre (2018) Brochure de L'approche des «Clubs des Mères». Available online: https://www.livelihoodscentre.org/documents/114097690/114438848/LRC.+Brochure+approche+Club+de+Me%CC%80res.pdf/823cdbe8-0649-3c0d-4947-7267693c5673?t=1580204839368 (accessed on 10 July 2021).

Lokonon, B.O.K. (2016) Urban households' attitude towards flood risk, and waste disposal: Evidence from Cotonou. *Int. J. Disaster Risk Reduct. 19*, 29–35.

Okoye, C. (2020) Risk Management Options for Flood Mitigation in West Africa. Available online: https://futureafricaforum.org/2020/06/11/risk-management-options-for-flood-mitigation-in-west-africa/ (accessed on 28 September 2021).

Padonou, E.A.; Gbaï, N.I.; Kolawolé, M.A.; Idohou, R.; Toyi, M. (2021) How far are mangrove ecosystems in Benin (West Africa) conserved by the Ramsar Convention? *Land Use Policy 108*, 105583. https://doi.org/10.1016/j.landusepol.2021.105583.

Panman, A.; Madison, I.; Kimacha, N.N.; Falisse, J.-B. (2021) Saving Up for a Rainy Day? Savings Groups and Resilience to Flooding in Dar es Salaam, Tanzania. *Urban Forum 33*, 13–33. https://doi.org/10.1007/s12132-021-09424-w.

Parkoo, E.N.; Thiam, S.; Adjanou, K.; Kokou, K.; Verleysdonk, S.; Adounkpe, J.G.; Villamor, G.B. (2022) Comparing Expert and Local Community Perspectives on Flood Management in the Lower Mono River Catchment, Togo and Benin. *Water 14*, 1536. https://doi.org/10.3390/w14101536.

Pinos, J.; Quesada-Román, (2022) A. Flood Risk-Related Research Trends in Latin America and the Caribbean. *Water 14*, 10. https://doi.org/10.3390/w14010010.

Pinter, N.; Huthoff, F.; Dierauer, J.; Remo, J.W.; Damptz, A. (2016) Modeling residual flood risk behind levees, Upper Mississippi River, USA. *Environ. Sci. Policy 58*, 131–140. https://doi.org/10.1016/j.envsci.2016.01.003.

Prettenthaler, F.; Albrecher, H.; Asadi, P.; Köberl, J. (2017) On flood risk pooling in Europe. *Nat. Hazards 88*, 1–20. https://doi.org/10.1007/s11069-016-2616-2.

Quesada-Román, A. (2022) Flood risk index development at the municipal level in Costa Rica: A methodological framework. *Environ. Sci. Policy 133*, 98–106. https://doi.org/10.1016/j.envsci.2022.03.012.

Quesada-Román, A.; Ballesteros-Cánovas, J.A.; Granados-Bolaños, S.; Birkel, C.; Stoffel, M. (2022) Improving regional flood risk assessment using flood frequency and dendrogeomorphic analyses in mountain catchments impacted by tropical cyclones. *Geomorphology 396*, 108000. https://doi.org/10.1016/j.geomorph.2021.108000.

Radermacher, R.; Dror, I.; Noble, G. (2006) Challenges and strategies to extend health insurance to the poor. In *Protecting the Poor: A Microinsurance Compendium*; Churchill, C., Ed.; Munich Re Foundation, Munich, Germany; pp. 66–93.

Ridolfi, E.; Di Francesco, S.; Pandolfo, C.; Berni, N.; Biscarini, C.; Manciola, P. (2019) Coping with Extreme Events: Effect of Different Reservoir Operation Strategies on Flood Inundation Maps. *Water 11*, 982. https://doi.org/10.3390/w11050982.

Riley, E. (2018) Mobile money and risk sharing against village shocks. *J. Dev. Econ. 135*, 43–58. https://doi.org/10.1016/j.jdeveco.2018.06.015.

Rothmann, K.J. (2012) *Epidemiology*: *An Introduction*, 2nd; Oxford University Press: Oxford, UK; ISBN 978-0-19-975455-7.

Sabharwal, C.L.; Anjum, B. (2016) Data Reduction and Regression Using Principal Component Analysis in Qualitative Spatial Reasoning and Health Informatics. *Polibits 53*, 31–42. https://doi.org/10.17562/PB-53-3.

Schäfer, L.; Waters, E.; Kreft, S.; Zissener, M. (2016) *Making Climate Risk Insurance Work for the Most Vulnerable: Seven Guiding Principles*; UNU-EHS Publication Series Policy Report No. 1; Munich Climate Insurance Initiative: Bonn, Germany. Available online: http://collections.unu.edu/eserv/UNU:5830/MCII_ProPoor_161031_Online_meta.pdf (accessed on 2 March 2022).

Schinko, T., Mechler, R.; Hochrainer-Stigler, S. (2019) The Risk and Policy Space for Loss and Damage: Integrating Notions of Distributive and Compensatory Justice with Comprehensive Climate Risk Management. In *Loss and Damage from Climate Change: Concepts, Methods and Policy Options, Climate Risk Management, Policy and Governance*; Mechler, R., Bouwer, L.M., Schinko, T., Surminski, S., Linnerooth-Bayer, J., Eds.; Springer: Cham, Switzerland; pp. 83–110.

Surminski, S.; Eldridge, J. (2017) Flood insurance in England—An assessment of the current and newly proposed insurance scheme in the context of rising flood risk. *J. Flood Risk Manag. 10*, 415–435. https://doi.org/10.1111/jfr3.12127.

Surminski, S.; Oramas-Dorta, D. (2014) Flood insurance schemes and climate adaptation in developing countries. *Int. J. Disaster Risk Reduct. 7*, 154–164. https://doi.org/10.1016/j.ijdrr.2013.10.005.

Tiepolo, M.; Galligari, A. (2021) Urban expansion-flood damage nexus: Evidence from the Dosso Region, Niger. *Land Use Policy*, *108*, 105547. https://doi.org/10.1016/j.landusepol.2021.105547.

The World Bank. (2018) Small but Smart: Benin and Togo Cooperate to Ensure Water Security. Available online: https://www.worldbank.org/en/news/feature/2018/01/25/small-but-smart-benin-and-togo-cooperate-to-ensure-water-security (accessed on 10 June 2021).

Thiam, S.; Salas, E.A.L.; Hounguè, N.R.; Almoradie, A.D.S.; Verleysdonk, S.; Adounkpe, J.G.; Komi, K. (2022) Modelling Land Use and Land Cover in the Transboundary Mono River Catchment of Togo and Benin Using Markov Chain and Stakeholder's Perspectives. *Sustainability 14*, 4160. https://doi.org/10.3390/su14074160.

Thieken, A.H.; Kienzler, S.; Kreibich, H.; Kuhlicke, C.; Kunz, M.; Mühr, B.; Müller, M.; Otto, A.; Petrow, T.; Pisi, S.; et al. (2016) Review of the flood risk management system in Germany after the major flood in 2013. *Ecol. Soc. 21*, 51. https://doi.org/10.5751/ES-08547-210251.

Thomas, A.; Leichenko, R. (2011) Adaptation through insurance: Lessons from the NFIP. *Int. J. Clim. Change Strateg. Manag. 3*, 250–263. https://doi.org/10.1108/17568691111153401.

Toussounon, A. (2010) Nangbéto: Quand la Source D'énergie Devient Source de Malheurs. Available online: https://www.podcastjournal.net/Nangbeto-Quand-la-source-d-energie-devient-source-de-malheurs_a5882.html (accessed on 10 July 2021).

Tourment, R.; Beullac, B.; Poulain, D. (2017) Management and Safety of Flood Defense Systems. In *Floods*; Vinet, F., Ed.; Elsevier: Amsterdam, The Netherlands; pp. 31–44, ISBN 9781785482694.

Treby, E.J.; Clark, M.J.; Priest, S.J. (2006) Confronting flood risk: Implications for insurance and risk transfer. *J. Environ. Manag. 81*, 351–359. https://doi.org/10.1016/j.jenvman.2005.11.010.

UN OCHA (2007a) OCHA Natural Disaster Bulletin: N° 8/Octobre 2007. Available online: https://reliefweb.int/sites/reliefweb.int/files/resources/0CDEFF8F9C8A732185257392005B3B60-Full_Report.pdf (accessed on 10 July 2021).

UN OCHA (2007b) West Africa—Floods: As of 27 September 07. Available online: https://reliefweb.int/sites/reliefweb.int/files/resources/2A3EBB3602FF36418525736400536822-ocha_FL_wa070927.pdf (accessed on 10 July 2021).

UNDRR (2021) Risk Transfer: Terminology. Available online: https://www.undrr.org/terminology/risk-transfer (accessed on 30 September 2021).

United Nations (2010) Bénin: Les Inondations Continuent, L'aide Parvient Aux Sinistrés. Available online: https://news.un.org/fr/story/2010/11/200062-benin-les-inondations-continuent-laide-parvient-aux-sinistres (accessed on 10 May 2021).

United Nations Economic Commission for Africa (2015) Rapport D'evaluation Sur L'intégration et la Mise en Oeuvre des Mesures de Réduction des Risques de Catastrophe au Togo. Available online: https://archive.uneca.org/sites/default/files/uploaded-documents/Natural_Resource_Management/drr/drr-in-togo_french_final.pdf (accessed on 10 May 2021).

Vert Togo (2019) Togo/Inondations: Le Débordement du Fleuve du Mono Fait un Mort à Klikamé. Available online: https://vert-togo.com/togo-inondations-le-debordement-du-fleuve-du-mono/ (accessed on 10 May 2021).

Vidal, R.; Ma, Y.; Sastry, S.S. (2016) *Generalized Principal Component Analysis;* Springer: New York, NY, USA; ISBN 978-0-387-87810-2.

Vigan, D.C. (2021) Débordement du Fleuve Mono: Au Moins Trois Communes en Proie Aux Inondations. Available online: https://lanation.bj/debordement-du-fleuve-mono-au-moins-trois-communes-en-proie-aux-inondations/ (accessed on 10 July 2021).

Wagner, S.; Souvignet, M.; Walz, Y.; Balogun, K.; Komi, K.; Kreft, S.; Rhyner, J. (2021) When does risk become residual? A systematic review of research on flood risk management in West Africa. *Reg. Environ. Chang. 21*, 84. https://doi.org/10.1007/s10113-021-01826-7.

Wetzel, M.; Schudel, L.; Almoradie, A.; Komi, K.; Adounkpè, J.; Walz, Y.; Hagenlocher, M. (2022) Assessing flood risk dynamics in data-scarce environments—Experiences from combining participatory Impact Chains with Bayesian Network Analysis in the Lower Mono River Basin, Benin. *Front. Water 4*, 837688.

Will, M.; Groeneveld, J.; Frank, K.; Müller, B. (2021) Informal risk-sharing between smallholders may be threatened by formal insurance: Lessons from a stylized agent-based model. *PLoS ONE 16*, e0248757. https://doi.org/10.1371/journal.pone.0248757.

Yazdani, M.; Mojtahedi, M.; Loosemore, M.; Sanderson, D. (2022) A modelling framework to design an evacuation support system for healthcare infrastructures in response to major flood events. *Prog. Disaster Sci. 13*, 100218. https://doi.org/10.1016/j.pdisas.2022.100218.

Yore, R.; Walker, J.F. (2019) Microinsurance for disaster recovery: Business venture or humanitarian intervention? An analysis of potential success and failure factors of microinsurance case studies. *Int. J. Disaster Risk Reduct. 33*, 16–32. https://doi.org/10.1016/j.ijdrr.2018.09.003.

4. What influences the demand for a potential flood insurance product in an area with low previous exposure to insurance? – a case study in the West African Lower Mono River Basin

Published originally as: Wagner S, Thiam S, Dossoumou NIP, Daou, D:. What influences the demand for a potential flood insurance product in an area with low previous exposure to insurance? – a case study in the West African Lower Mono River Basin (LMRB). Economics of Disasters and Climate Change 8, 1–32 (2024). https://doi.org/10.1007/s41885-023-00138-w

Abstract:

Floods portray a severe problem in the riverine areas of West Africa while more frequent and intense heavy precipitation events are projected under climatic change scenarios. Already, floods cause manifold impacts, leaving the population to cope with the financial impacts of floods through their own means. As formal risk transfer mechanisms (e.g., insurance) are not yet widely available to the population, efforts to increase their accessibility are being intensified. However, studies assessing flood insurance demand currently mostly focus on regions with more established markets. Also, they are majorly applying conventional statistical modeling approaches that consider only a small number of parameters. Contrarily, this study aims to provide an approach for assessing flood insurance in a context of low previous exposure to such products, to allow for a better consideration of the research context. Therefore, a parameter selection framework is provided and machine learning and deep learning models are applied to selected parameters from an existing household survey data set. In addition, the deep learning sequential neural networks outperformed all machine learning models achieving an accuracy between 93.5 - 100% depending on the loss function and optimizer used. The risk to be covered, insurance perception, no access to any source, access to support from community solidarity funds, access to governmental support, or drawing upon own resources for financial coping, financial recovery time, lack of means and prioritizing more essential needs emerged as important model parameters in researching insurance demand. Future roll-out campaigns could consider the parameters pointed out by this study.

Keywords: floods, machine learning, deep learning, willingness to insure, Togo, Benin

4.1 Introduction

Over the past decades, there have been observations of an increasing trend of hydrological extremes (i.e. maximum peak discharge) in West Africa, leading to an increase of disastrous flood events in areas located in proximity to large rivers (Ranasinghe et al. 2021). Moreover, while overall precipitation is

projected to decrease in West Africa, heavy precipitation events are expected to occur more frequently and intensively according to scenarios considering medium to high emission levels, which leads to accumulated hydro-climatic stress through drought and flood events in the region (Trisos et al. 2022, Giorgi et al. 2019). Already, floods cause a wide variety of impacts in West Africa, such as damaged buildings, disruption of livelihoods, damaged goods, fatalities, displacement, sickness and spreading of diseases, damaged infrastructure and crop damage (Wagner et al. 2021, Afriyie et al. 2018, Brisibe and Pepple 2018, Addo and Danso 2017, Ahadzie et al. 2016, Enete et al. 2016, Adewole et al. 2015, Adelekan and Fregene 2015, Codjoe et al. 2014). With regards to the financial implications of flood impacts in the Lower Mono River Basin (LMRB) in particular, it was found that floods regularly affect households financially through agricultural (lost investments through loss and destruction of crops and plantations, loss of livestock), material (repair and replacement cost for damage or destruction of residential houses and personal material belongings), health (sickness and subsequent payment for medical care), and commercial/trade impacts (lost income from damaged stored products for sale, lack of market access, and affected marketplaces) (Wagner et al. 2022). While mutual support among affected households, especially in the phases of response and reconstruction (especially hosting flood victims and helping neighbors to rebuild) (Lamond et al. 2019, Amoako et al. 2019, Ahadzie et al. 2016, Codjoe and Issah 2016, Adelekan and Asiyanbi 2016), seems to be very prevalent in the West African region, there appears to be a lack of risk transfer instruments that are designed to address the financial consequences of floods (Wagner et al. 2021). Thus, people in the region frequently resort to informal mechanisms that are not originally designated for alleviating the diverse financial implications of flood impacts, which sets households back in their financial achievements (Wagner et al. 2022, Boubacar et al. 2017, Addo and Danso 2017).

Moreover, the frequency and severity of flood impact levels in the LMRB require more concerted risk reduction activities before establishing risk transfer mechanisms, such as insurance, that enable spreading the risk of financial losses across a larger pool of beneficiaries (Wagner et al. 2022). Also, whether insurance is an appropriate risk management tool in developing economies or not remains a contested issue (Pill 2022, Mechler and Deubelli 2021, Dehm 2020, Linnerooth-Bayer et al. 2019, Schäfer et al. 2019, Gewirtzman et al. 2018). While there are increased efforts to raise insurance penetration and insurance coverage against climate-related extreme events in developing economies (InsuResilience Global Partnership 2021), insurance protection against flood impacts remains difficult to be established, even globally (Léger 2022, Flood Resilience Initiative 2020, Lloyd's 2018). In addition, much of the research on the uptake of or willingness to pay for flood insurance focusses on the Asian, North American and European region, in which the establishment of flood insurance in the market and familiarity with such products are very different from the West African region. Aside from a few

studies (Berg et al. 2022, Oduniyi et al. 2020, Navrud and Vondolia 2020, Adzawla et al. 2019), this topic has not been widely researched in the African context. Also, insurance penetration on the African continent in general is only half of the global average while also the average premiums per person are eleven times lower (Bagus et al. 2020). Thus, to better inform future roll-out campaigns of flood insurance products it is important to research the parameters that are associated with insurance take-up in settings where a large number of people at risk have not yet been insurance customers, such as the LMRB.

Most studies researching the willingness to insure (WTI) against floods/willingness to pay (WTP) rely on parameter selection directly based on literature and subsequently apply regression methods (Netusil et al. 2021, Robinson and Botzen 2019, Reynaud et al. 2018, Fahad and Jing 2018, Turner et al. 2014, Botzen et al. 2013, Botzen and van den Bergh 2012), that usually only consider a low number of parameters. Contrarily, it presents a challenge to derive such parameters from a considerable body of studies for the West African region, due to the limited number of available publications from this area. Thus, established frameworks or reasons for parameter inclusion from other contexts might not be the best fitting for this research context. To address this gap, this study investigates the following central research question: Which parameters influence the decision-making process of households in the LMRB to take up a potential insurance product against flood damages in a setting with low previous exposure to such products?

Constrained by the limited literature base for the West African region, this study initially reviews literature on WTI against floods/WTP for flood insurance on a global scale. Based on this body of literature, a framework is developed that summarizes six thematic areas of parameters (subjective perception of flood risk, objective flood risk, interactions with insurance institutions, Interaction with other institutions & social environment, attributes of HH/individuals, assets to be potentially insured) to guide which factors are influential on the demand for insurance in the research setting. To structure the parameter selection, feature columns for the entire data set were initially assessed for the entire data set. Then, the remaining parameters were categorized into the six thematic areas of the framework. Moreover, the grouped parameters were assessed through pairplots and a heatmap correlation matrix. As a final step of verification, crosstabs were used for assessing the correlation between the parameters and the output value. This data-driven parameter selection approach is deemed suitable for this study due to researching a context in which people at risk have not been widely exposed to insurance products. Subsequently, on the basis of the selected parameters, machine learning and deep learning models are trained that serve in explaining the observed demand for a potential flood insurance product in the research area.

4.2 Background

4.2.1 Insurance and risk transfer for floods in Togo and Benin

Currently, insurance products against the impacts of floods are not widely offered on a household level in Togo and Benin. The insurance industry is mostly centered around motorcycle/car insurance and less on natural hazards (Meton 2019). In addition, there are efforts in Benin to establish health insurance in pilot communities free of charge for its beneficiaries in the first three years (Government of the Republic of Benin 2021). With regards to floods, calls for a feasibility assessment of a flood insurance system through a national insurance fund are even dating back to at least 2011, as stated in a post-disaster needs assessment of the 2010 floods (Government of the Republic of Benin 2011). Also, the Togolese government expressed a strong interest in feasibility studies of an agricultural insurance system within its National Adaptation Plan (Government of the Republic of Togo 2017). In addition, in 2018 Togo was chosen by the pan-African risk pool mechanism African Risk Capacity (ARC) to serve as a pilot country for the implementation of a flood insurance scheme (Akoda 2018). However, no information on its current status could be found, and the most recent available report for the Togolese Republic only contains information for the event of drought (African Risk Capacity 2021b), similarly for Benin (African Risk Capacity 2021a). Moreover, the Beninese government also stated a practical absence of an insurance system for climate-related impacts, such as floods, droughts, wind storms, or heat waves, despite their potentially high impact on the country's gross domestic product (Government of the Republic of Benin 2020). Regarding the LMRB in particular, a recent study points out a strong need for risk-reducing flood adaptation measures and that a conventional, market-based flood insurance approach could be impractical due to the high severity and frequency levels of reported flood impacts from a household perspective (Wagner et al. 2022). As a consequence, this study aims to show relevant insights into the potential flood insurance market, for the case that risk-reducing flood adaptation measures are successfully implemented in the LMRB. Moreover, the research provides insight for insurers to see if they could help to opening a market for themselves by contributing to investing into flood adaptation measures in the area. Finally, this research could benefit the previously mentioned endeavors of establishing flood insurance that are already taking place and support their potential rollout campaigns.

4.2.2 Studies researching the demand for flood insurance

Various studies on the demand for insurance and their influential factors have been published in the past years under the fields of willingness to pay (WTP) or willingness to insure (WTI). Whereas the former stride is mainly focusing on calculating a premium that potential insurance clients are willing to pay, the latter usually researches the general interest level among targeted groups. The latter aspect also portrays the main focus of this study. However, only a small number has researched the influential factors on demand for flood insurance in the African context (Berg et al. 2022, Oduniyi et al. 2020, Navrud and Vondolia 2020, Adzawla et al. 2019). The major share of studies from that stride of research focused on the Asian (Hossain et al. 2022, Senapati 2020a, 2020b, Liu et al. 2019, Dewi et al. 2018, Reynaud et al. 2018, Sidi et al. 2018, Fahad and Jing 2018, Arshad et al. 2016, Ren and Wang 2016, Abbas et al. 2015, Aliagha et al. 2015, Aliagha et al. 2014, Turner et al. 2014, Hung 2009), North American (Darlington and Yiannakoulias 2022, Huang and Lubell 2022, Netusil et al. 2021, Thistlethwaite et al. 2020, Atreya et al. 2015, Oulahen 2015, Kousky 2011, Browne and Hoyt 2000) or European contexts (Osberghaus and Reif 2021, Robinson and Botzen 2020, Robinson and Botzen 2019, Botzen et al. 2013, Seifert et al. 2013, Botzen and van den Bergh 2012) – areas in which flood insurance systems and insurance in general are more widely established. In studies from this stride of research, the influential factors mentioned have often been grouped into different categories to provide better orientation for researchers in the selection of relevant parameters (summarized in Table 1). For example, Seifert et al. (2013) state the influence of perceptions of flood risks (subjective views), experiences with flood impacts (objective views) as well as factors relating to interactions with disaster assistance from institutions (humanitarian/public compensation). Similarly, Netusil et al. (2021) also point out the importance of factors expressing subjective and objective views on flood risk, while adding the characteristics of residential houses (assets) and demographic characteristics of the respondents (attributes of HH/individual). Aliagha et al. (2014) as well raise the influence of objective and subjective views on flood risk and socio-economic/demographic factors. To achieve its objective, this study compiles further influential factors from further WTP/WTI studies from a global scope/various geographical contexts and grouped them as well into distinct categories while drawing upon and complementing the suggested categories from the previously mentioned studies. In that way, a framework to support the selection of influential factors was created for this study (Figure 4.1).

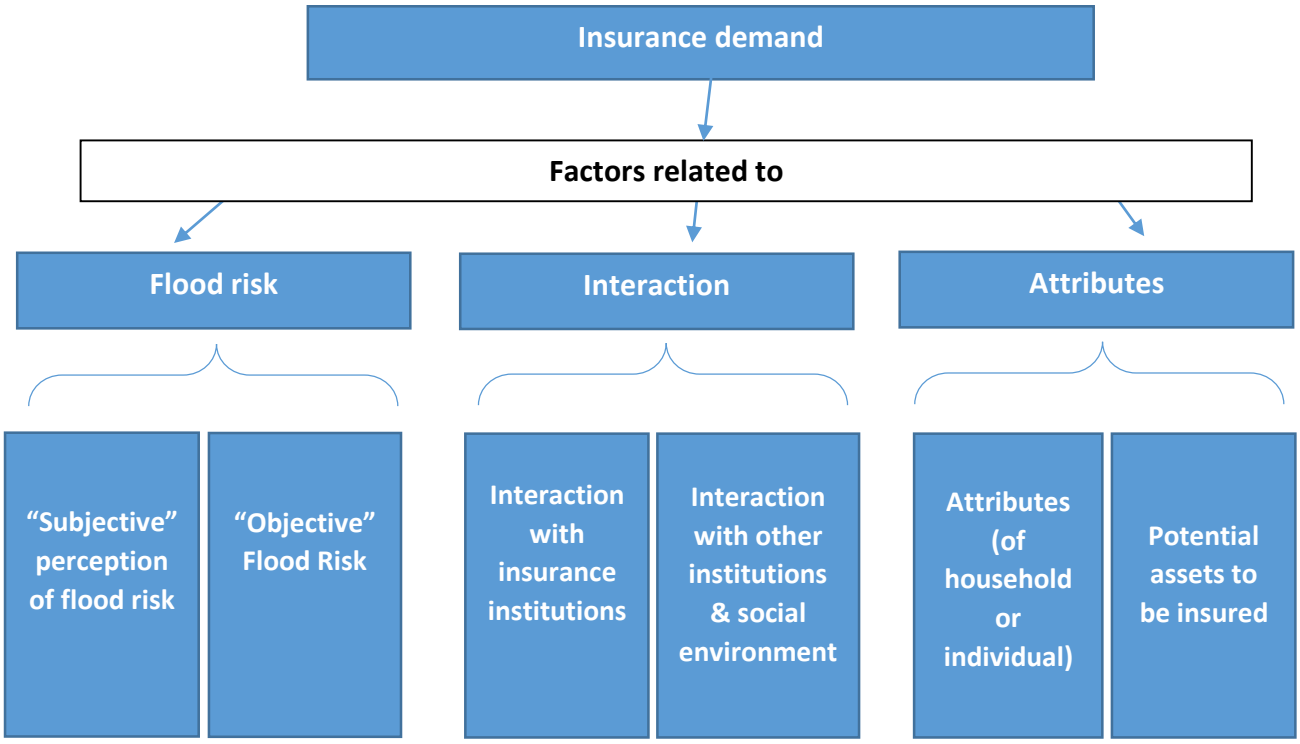


Figure 4.1: Factors mentioned in literature about influential factors of insurance demand; own figure, grouping of thematic areas based on (Netusil et al. 2021, Aliagha et al. 2014, Seifert et al. 2013).

In the studies reviewed, generally there are two major strides of influential factors that can be identified with regards to flood risk. On the one hand, there are studies that emphasize the importance of flood risk-related parameters from a "subjective" perspective, such as flood risk perception (Hossain et al. 2022, Reynaud et al. 2018, Oulahen 2015, Seifert et al. 2013, Botzen and van den Bergh 2012, Hung 2009), (recently) experienced flood events and impacts (Osberghaus and Reif 2021, Senapati 2020a, Liu et al. 2019, Adzawla et al. 2019, Fahad and Jing 2018, Ren and Wang 2016, Atreya et al. 2015, Aliagha et al. 2014, Turner et al. 2014, Hung 2009, Browne and Hoyt 2000), perception on climate change (Adzawla et al. 2019, Oulahen 2015, Botzen and van den Bergh 2012), awareness (Senapati 2020b), anticipated worry and regret about uninsured losses (Robinson and Botzen 2020, Robinson and Botzen 2019), and the observation of other's losses (Turner et al. 2014). On the other hand, there are studies that point out the significance of flood risk-related parameters from an "objective" perspective, such as the externally defined level of flood risk (Huang and Lubell 2022, Netusil et al. 2021, Kousky 2011), proximity to rivers (Sidi et al. 2018, Botzen and van den Bergh 2012, Kousky 2011), living in a low lying area (Botzen and van den Bergh 2012), house elevation (Aliagha et al. 2015), experienced flood impacts (Hossain et al. 2022, Osberghaus and Reif 2021, Paopid et al. 2020, Senapati 2020a, Liu et al. 2019, Fahad and Jing 2018, Reynaud et al. 2018, Arshad et al. 2016,

Oulahen 2015, Atreya et al. 2015, Turner et al. 2014, Seifert et al. 2013, Hung 2009, Browne and Hoyt 2000), flood depth and duration (Paopid et al. 2020, Aliagha et al. 2015), presence of other risk-reduction measures/levee protection (Hossain et al. 2022, Thistlethwaite et al. 2020, Kousky 2011).

Also, there is a body of literature that presents the significance of parameters that relate to experiences that people at risk have made with institutions/actors that are potentially involved in post-disaster compensation (such as insurance companies, NGOs, governmental agencies or family/friends). Relevant factors that relate to experiences made with insurance in particular include the price of insurance (Navrud and Vondolia 2020, Reynaud et al. 2018, Browne and Hoyt 2000), multi-year insurance policies/billing frequency (Reynaud et al. 2018, Botzen et al. 2013), the amount offered in the insurance contract (Senapati 2020a, Reynaud et al. 2018), trust in insurers (Sidi et al. 2018, Reynaud et al. 2018, Aliagha et al. 2014), types of risk covered (Reynaud et al. 2018), previous insurance purchase (Senapati 2020a), insurance provider (Reynaud et al. 2018), perception of effectiveness of insurance (Abbas et al. 2015), and awareness of insurance (understanding) (Oduniyi et al. 2020, Senapati 2020b). Also, there are parameters that relate to the "wider" social environment and its role in flood risk management such as the perceived responsibility for preventing damage (Oulahen 2015), humanitarian/public compensation (Seifert et al. 2013, Botzen and van den Bergh 2012), flood risk communication (Botzen et al. 2013), flood prediction (warning) (Sidi et al. 2018), access to information and extension services (Hossain et al. 2022, Adzawla et al. 2019), membership in farmer's groups (Hossain et al. 2022, Adzawla et al. 2019), perception towards government effort in handling flood (Sidi et al. 2018), risk sharing between agents (Berg et al. 2022), and social influence (Lo 2013).

In addition, there are various studies that emphasize the influence of attributes of households/individuals as well as potential assets to be insured. Examples of the former include income (Dewi et al. 2018, Sidi et al. 2018, Arshad et al. 2016, Ren and Wang 2016, Aliagha et al. 2015, Abbas et al. 2015, Aliagha et al. 2014, Kousky 2011, Hung 2009, Browne and Hoyt 2000), education (Oduniyi et al. 2020, Adzawla et al. 2019, Sidi et al. 2018, Atreya et al. 2015), age (Oduniyi et al. 2020, Atreya et al. 2015, Abbas et al. 2015), ethnicity (Atreya et al. 2015), attitudes towards risk taking (e.g., risk averse) (Hossain et al. 2022, Reynaud et al. 2018, Botzen and van den Bergh 2012), internal locus of control (Robinson and Botzen 2020), ability to pay (Fahad and Jing 2018, Arshad et al. 2016), alternative income sources (non-agricultural) (Hossain et al. 2022, Adzawla et al. 2019, Abbas et al. 2015), preference uncertainty (Hung 2009), conservatism (Hung 2009), farmer's experience (Oduniyi et al. 2020), marital status (Oduniyi et al. 2020), HH dependents (Oduniyi et al. 2020), remittances (Adzawla et al. 2019), and having the location of the house in an affluent area (Adzawla et al. 2019). Studies that mention the latter are pointing out house price/dwelling value (Darlington and

Yiannakoulias 2022, Paopid et al. 2020, Kousky 2011), amount of land owned (Kousky 2011), land status (ownership) (Dewi et al. 2018, Abbas et al. 2015), farm typology (Fahad and Jing 2018, Arshad et al. 2016), cultivated land size (Senapati 2020a), farm size (Dewi et al. 2018), seed prices (Senapati 2020a), fertilizer prices (Senapati 2020a), expenditure of farmer (Dewi et al. 2018), house conditions (Hung 2009), and commercial production (Adzawla et al. 2019).

Most studies researching the willingness to insure (WTI) against floods/willingness to pay (WTP) rely on parameter selection directly based on literature and subsequently apply regression methods, such as least-squares-, logit-, linear-, and Tobit-models (Netusil et al. 2021, Robinson and Botzen 2019, Reynaud et al. 2018, Fahad and Jing 2018, Turner et al. 2014, Botzen et al. 2013, Botzen and van den Bergh 2012). Nonetheless, the application of those methods will not allow for analyzing a larger amount of parameters, and mean using a simplistic model, implying the use of several hypotheses and with high uncertainties. Regarding the lack of studies and lack of widespread previous exposure to such products in the West African context, a synthesis of factors based on studies from various regions will assist in the selection of parameters that could prove to be influential in assessing a household's interest level in a potential insurance product. To structure the parameter selection, feature columns for the entire data set were initially assessed for the entire data set. Then, the remaining parameters were categorized into the six thematic areas of the framework (Figure 4.1). Moreover, the grouped parameters were assessed through pairplots and a heatmap correlation matrix. As a final step of verification, crosstabs were used for assessing the correlation between the parameters and the output value. As a subsequent step, machine learning and a deep learning models on neural networks were trained on the basis of the selected parameters that serves in predicting the demand for a potential flood insurance product in the LMRB.

The aim of this research is to deliver a basis in case decision makers decide to launch a roll out concept of a flood insurance product in this area where insurance penetration is still very low. Moreover, this study also aims to generate an approach that is applicable to research the demand for insurance in other contexts and regions. The approach can serve as a framework for follow-up studies assessing the willingness to insure in contexts that have not yet been exposed much to insurance before and beyond. Therefore, this study assesses the question of which parameters influence the decision-making process of households in the LMRB to take up insurance against flood damages in a setting where people have barely been exposed to such products before?

Table 4.1: Summary of parameters mentioned in WTP/WTI studies

Category	Thematic area	Parameter	References	Comparable parameter in survey data set
Flood risk	**"Subjective" perception of flood risk**	**Flood risk perception**	(Hossain et al. 2022, Reynaud et al. 2018, Oulahen 2015, Seifert et al. 2013, Botzen and van den Bergh 2012, Hung 2009)	**Yes**
		Recently) experienced flood events	(Osberghaus and Reif 2021, Senapati 2020a, Liu et al. 2019, Adzawla et al. 2019, Fahad and Jing 2018, Ren and Wang 2016, Atreya et al. 2015, Aliagha et al. 2014, Turner et al. 2014, Hung 2009, Browne and Hoyt 2000)	**Yes**
		Perception on climate change	(Adzawla et al. 2019, Oulahen 2015, Botzen and van den Bergh 2012)	**Yes**
		Awareness	(Senapati 2020b)	**Yes**
		Anticipated worry and regret about uninsured losses	(Robinson and Botzen 2020, Robinson and Botzen 2019)	**Yes**
		The observation of other's losses	(Turner et al. 2014)	**Yes**
	"Objective" Flood Risk	**(Externally defined) level of flood risk**	(Huang and Lubell 2022, Netusil et al. 2021, Kousky 2011)	**Yes**
		Proximity to rivers	(Sidi et al. 2018, Botzen and van den Bergh 2012, Kousky 2011)	Indirectly contained in other parameter of flood risk
		Living in a low lying area	(Botzen and van den Bergh 2012)	Indirectly contained in other parameter of flood risk
		House elevation	(Aliagha et al. 2015)	**Yes**
		Experienced flood impacts	(Hossain et al. 2022, Osberghaus and Reif 2021, Paopid et al. 2020, Senapati 2020a, Liu et al. 2019, Fahad and Jing 2018, Reynaud et al. 2018, Arshad et al. 2016, Oulahen 2015, Atreya et al. 2015, Turner et al. 2014, Seifert et al. 2013, Hung 2009, Browne and Hoyt 2000)	**Yes**

		Flood depth and duration	(Paopid et al. 2020, Aliagha et al. 2015)	**Yes**
		Presence of other risk-reduction measures/levee protection	(Hossain et al. 2022, Thistlethwaite et al. 2020, Kousky 2011)	**Yes**
Interaction	**Interaction with insurance institutions**	**Price of insurance**	(Navrud and Vondolia 2020, Reynaud et al. 2018, Browne and Hoyt 2000)	No
		Multi-year insurance policies/billing frequency	(Reynaud et al. 2018, Botzen et al. 2013)	No
		The amount offered in the insurance contract	(Senapati 2020a, Reynaud et al. 2018)	No
		Trust in insurers	(Sidi et al. 2018, Reynaud et al. 2018, Aliagha et al. 2014)	**Yes**
		Types of risk covered	(Reynaud et al. 2018)	**Yes**
		Previous insurance purchase	(Senapati 2020a)	**Yes**
		Insurance provider	(Reynaud et al. 2018)	**Yes**
		Perception of effectiveness of insurance	(Abbas et al. 2015)	**Yes**
		Awareness of insurance (understanding)	(Oduniyi et al. 2020, Senapati 2020b)	**Yes**
	Interaction with other institutions & social environment	**Perceived responsibility for preventing damage**	(Oulahen 2015)	**Yes**
		Humanitarian/public compensation	(Seifert et al. 2013, Botzen and van den Bergh 2012)	**Yes**
		Flood risk communication	(Botzen et al. 2013)	**Yes**
		Flood prediction (warning)	(Sidi et al. 2018)	**Yes**
		Access to information and extension services	(Hossain et al. 2022, Adzawla et al. 2019)	**Yes**
		Membership in farmer's groups	(Hossain et al. 2022, Adzawla et al. 2019)	**Yes**

		Perception towards government effort in handling flood	(Sidi et al. 2018)	**Yes**
		Risk sharing between agents	(Berg et al. 2022)	**Yes**
		Social influence	(Lo 2013)	No
Attributes	**Attributes (of HH/individual)**	**Income**	(Dewi et al. 2018, Sidi et al. 2018, Arshad et al. 2016, Ren and Wang 2016, Aliagha et al. 2015, Abbas et al. 2015, Aliagha et al. 2014, Kousky 2011, Hung 2009, Browne and Hoyt 2000)	**Yes**
		Education	(Oduniyi et al. 2020, Adzawla et al. 2019, Sidi et al. 2018, Atreya et al. 2015)	**Yes**
		Age	(Oduniyi et al. 2020, Atreya et al. 2015, Abbas et al. 2015)	**Yes**
		Ethnicity	(Atreya et al. 2015)	**Yes**
		Attitudes towards risk taking (e.g., risk averse)	(Hossain et al. 2022, Reynaud et al. 2018, Botzen and van den Bergh 2012)	**Yes**
		Internal locus of control	(Robinson and Botzen 2020)	**Yes**
		Ability to pay	(Fahad and Jing 2018, Arshad et al. 2016)	**Yes**
		Alternative income sources (non-agricultural)	(Hossain et al. 2022, Adzawla et al. 2019, Abbas et al. 2015)	**Yes**
		Preference uncertainty	(Hung 2009)	**Yes**
		Conservatism	(Hung 2009)	No
		Farmer's experience	(Oduniyi et al. 2020)	**Yes**
		Marital status	(Oduniyi et al. 2020)	**Yes**
		HH dependents	(Oduniyi et al. 2020)	**Yes**

		Remittances	(Adzawla et al. 2019)	**Yes**
		Having the location of the house in an affluent area	(Adzawla et al. 2019)	No
	Potential assets to be insured	**House price/dwelling value**	(Darlington and Yiannakoulias 2022, Paopid et al. 2020, Kousky 2011)	No
		Amount of land owned	(Kousky 2011)	**Yes**
		Land status (ownership)	(Dewi et al. 2018, Abbas et al. 2015)	**Yes**
		Farm typology	(Fahad and Jing 2018, Arshad et al. 2016)	**Yes**
		Cultivated land size	(Senapati 2020a)	No
		Farm size	(Dewi et al. 2018)	No
		Seed prices	(Senapati 2020a)	No
		Fertilizer prices	(Senapati 2020a)	No
		Expenditure of farmer	(Dewi et al. 2018)	No
		House conditions	(Hung 2009)	**Yes**
		Commercial production	(Adzawla et al. 2019)	No

4.3 Methods: Data collection and analysis

4.3.1 Data collection: Household survey

The data collection process for this study comprised of a household survey carried out in 2021 in the period of March - April. Data was collected by approaching the LMRB based on selected villages located in a low, medium or high flood risk zone. Those flood risk zones were distinguished by criteria of their distance to the river as well as elevation levels. Out of those flood risk zones, 24 villages were selected based on levels of flood-affectedness mentioned in media or situational assessment reports (Figure 4.2).

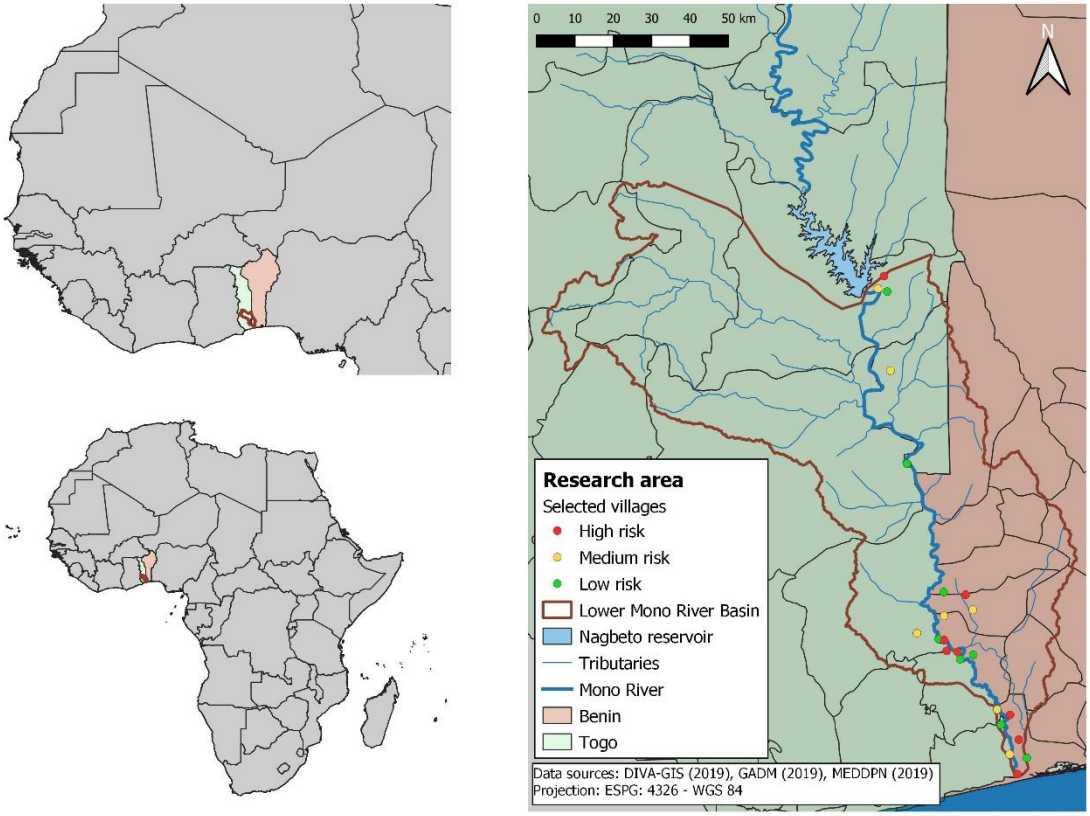


Figure 4.2: Location of research area and selected villages

The selection of households within the selected villages took place by drawing a censored proportional sample (11.2%) from each village. The interviewers selected the households randomly by starting out from a centrally located and easily identifiable point in the village and then select houses along a randomly selected walking direction at a randomly selected interval (Levy and Lemeshow 2008). The interviewers then repeated the process, as soon as they arrived at the end of the village. The data collection took place in the scope of the joint research project CLIMAFRI in which several project partners surveyed households.

Table 4.2: Summary of basic household characteristics

Parameters	Responses	Frequency	Percentage
Country of residence	Togo	496	66.7
	Benin	248	33.3
	Total	744	100
Gender of respondent	Female	296	39.8
	Male	488	60.2
	Total	744	100
Relationship of respondent to head of household	Head of household	508	68.3
	Spouse of the head of household	213	28.6
	Daughter/son of head of household	15	2.0
	Parent of head of household	1	0.1
	No response/others	7	0.9
	Total	744	100
Marital status	Married	656	88.2
	Widow/widower	53	7.1
	Single	25	3.4
	Divorced/seperated	10	1.3
	Total	744	100
Household is female-headed	Yes	81	10.9
	No	663	89.1
	Total	744	100
Age of respondent	Below 25 years	30	4.0
	Between 25 and 50 years	472	63.5
	Above 50 years	242	32.5
	Total	744	100
Size of household	Small (1-4 members)	162	21.8
	Medium (5-8 members)	355	47.7
	Large (>8 members)	227	30.5
	Total	744	100
Household income per year (in CFA)	Up to 100 000	140	18.8
	> 100 000 – 200 000	173	23.2
	> 200 000 – 300 000	185	24.9
	More than 300 000	226	30.4
	No response	20	2.7
	Total	744	100
Highest level of education in household	None completed	51	6.9
	Primary	213	28.6
	Secondary	394	53.0
	University	84	11.3
	No response	2	0.2
	Total	744	100
Level of agricultural dependency	Low dependency (< 25%)	29	3.9
	Medium dependency (25%-<50%)	132	17.7
	High dependency (50% -<75%)	389	52.3
	Very high dependency (75% - 100%)	194	26.1
	Total	744	100
Additional sources of income (multiple responses possible)	Raising cattle	213	28.6
	Fishing	86	11.6
	Hunting	7	0.9
	Local industries	188	25.3
	Manufacturing industries	14	1.9
	Construction and public works	13	1.7
	Commerce, catering and accomodation	182	24.5
	Transport and communication	26	3.5
	Banks and insurance	1	0.1
	No response	91	12.2
Currently owning any form of insurance	Yes	17	2.3
	No	727	97.7
	Total	744	100
Previously owned insurance but terminated the contract	Yes	8	1.1
	No	736	98.9
	Total	744	100

The questionnaire yielded a data set shared among project partners (e.g. Dossoumou et al. 2023) containing more than 400 parameters from 744 households with data, among others, on household characteristics and assets, experiences with floods, flood risk perception, flood impacts, financial coping mechanisms, experience with and perception of insurance, willingness to buy of a potential product. A summary of the basic household characteristics is provided in Table 4.2. This data set provided a highly suitable basis to carry out the data-driven analysis approach of this study, applying machine and deep learning methods that consider a wider range of parameters than conventional statistical modeling approaches. Moreover, the research area proved to be highly suitable to research the demand for insurance in a setting with low previous exposure to insurance products. Only 2.3% among the interviewed population had any form of insurance at the time of data collection and 1.1% had insurance previously yet terminated it before the data collection.

4.3.2 Data analysis

The aim of this study is to predict the level of interest of an interviewee being inclined to purchase a potential flood insurance product. As illustrated in Figure 4.3, the target classes of the generated models are divided into five different responses (very likely, likely, indifferent, unlikely, very unlikely). The respondents of the questionnaire expressed a higher level of interest within the Togolese subset as compared to the Beninese subset.

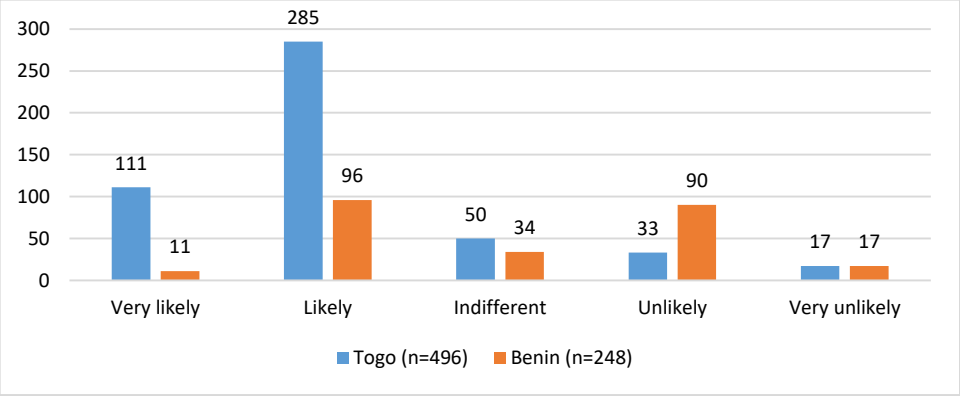


Figure 4.3: Distribution of responses within outcome variable (likelihood of purchase of a potential flood insurance product)

Usually, WTP/WTI studies look at the amount of money that respondents would be willing to spend on/the general level of interest in buying one specific insurance type. This study differs slightly by asking for the level of interest in flood insurance, while leaving it up to the respondent to choose one of four different forms of coverage (agricultural, material, health, and commercial impacts from

floods) in a hypothetical policy. Due the current absence and hypothetical nature of flood risk-related insurance products in the research area this study refrained from researching a monetary value in order to better avoid generating false expectations among the interviewees. In that sense this study is aiming at solve a classification and not a regression problem. In addition, this study aims at providing helpful information for shaping a potential flood risk insurance product for the LMRB in case it will be pursued at some point. All analyses were performed in Python.

4.3.2.1 Data preparation and variable selection

Initially, data had to be separated into categorical and numerical parameters while cleaning the data and removing NaN (Not a Number) values. The latter was necessary since the presence of NaN values will stop the calculation of fitting the model if not removed, but will also generate NaN values after calculation. For the creation of the model, one-hot encoding was used for the categorical parameters (transformation into binary 0-1 parameters) and standard scaling for the numerical data (discarding mean and scaling according to variance of the unit) to be able to create a processor for the model.

The process of parameter selection is illustrated in Figure 4.4. In order to begin the initial selection of relevant parameters, feature columns were assessed based on the p-value and (Spearman) correlation value to uncover the relationships between parameters. This steps allowed for a reduction of the initially more than 400 parameters to around 100. The remaining parameters were then grouped by topic into the six areas of the framework presented in Figure 4.1. Then, pair plots (showcasing pairwise bivariate distributions) and a (Pearson) correlation heat map were generated to further facilitate the selection of influential parameters. Based on the heat map correlation matrix, it was decided to use the parameters with low correlation values while disregarding the others, as the high correlation parameters can be connected and related in two ways: if the values of correlation are higher than +0.5, then these parameters are directly correlated and if less than -0.5 then they are inversely correlated, which means if one parameter tends to increase, then the connected one decrease for negative values while it increases for positive values. For additional verification, cross-tabulations that illustrate the correlations between the parameters and the output parameter were used before further steps were conducted in the analysis. Moreover, it allowed for deciding which parameters to retain or drop.

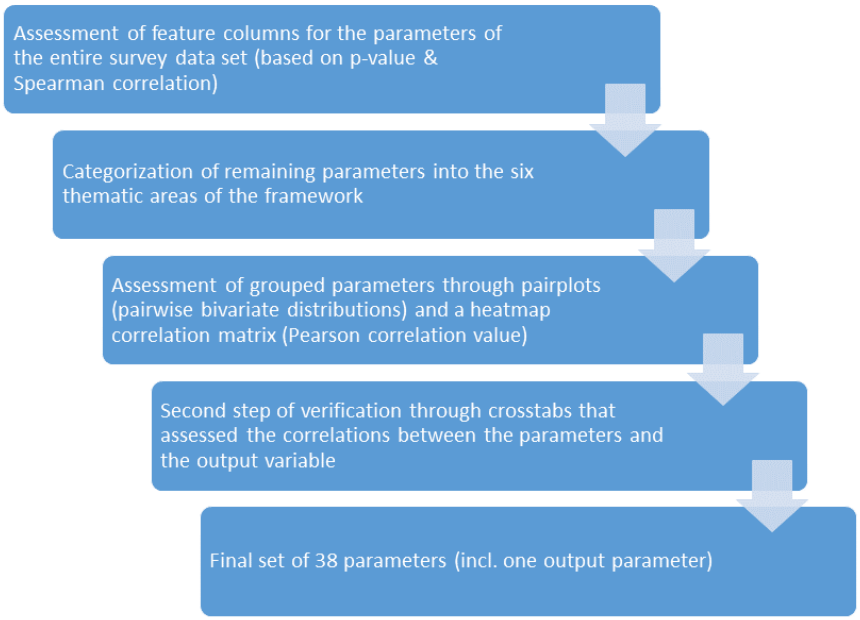


Figure 4.4: Selection process of the final set of model parameter

4.3.2.2 Comparison of machine learning models

Machine learning models were tested by using the Scikit-learn sklearn package. For all models, the data was split into training (67%) and test data (33%). The first model was the multinomial logistic regression model, and is considered a supervised learning technique. This technique serves to predict if an object belongs to a certain class by providing a probability on a range between 0 and 1 (James et al. 2021). Furthermore, the Histogram-based Gradient Boosting classifier model was applied, which considers gradient values obtained by prior update steps from moving into the steepest direction of descent (Feng et al. 2018). Also hyperparameter tuning and gridsearch were applied to this classifier, which however did not lead to a satisfactory improvement of the model accuracy. Finally, additional machine learning tests were applied by using decision trees, a method drawing upon the Gini-Index (James et al. 2021). In addition, bagging was applied to the decision trees to lower the variance in the prediction function, as well a random forest model, drawing upon an assembly of various decision trees (Hastie et al. 2009).

4.3.2.3 Deep learning model (Sequential neural network)

In order to attempt achieving better results than the ones obtained from more conventional machine learning approaches (see 4.3.2.2), this study added a deep learning (DL) model (sequential neural network model) to the analysis using both the TensorFlow and Keras packages. Sequential models are part of artificial neural networks, which usually consist of several layers (input layer, hidden layers,

and output layer) that each are equipped with several nodes/neurons, containing activation functions, that are connected through weighted connections between the layers (Jung 2022, James et al. 2021). In general, a sequential model processes the inputted data in a one-directional, linear sequence from the input layer, passing through the hidden layers, and arriving at the output layer (Chollet 2021). Usually, DL approaches are chosen in cases where extremely large data sets are processed and when the possibility to interpret the model does not play and important role (James et al. 2021). Still, this study applied this approach to clarify if a DL model would improve the accuracy of prediction. With regards to the large amount of categorical data, that were encoded, it also helped to consider a larger amount of available data. To analyze numerical and categorical features in a combined manner in this DL model, feature columns were defined by using a Dense Features layer and using it as an input into the Keras model. The sequential model built for this study uses the Relu (Rectified Linear Unit) activation function for the input layer, not allowing activation of the neuron if input values are below 0 (James et al. 2021), and a Softmax function for the output layer, which is best suited if a categorical output is desired (Klimo et al. 2021). Each neuron of the input layer receives a variable of the dataset and passes that information to another neuron, which leads to a higher number of neurons with a higher number of variables. This model contains 256 neurons. Besides, the Softmax layer must have the same number of nodes as the output layer, which is five in the case of this model (Figure 4.5). The activation layer is actually the nonlinear function and it transforms the values of the first hidden layer into weighted sums to the next layer. In addition, the Adam as optimizer with a cross entropy and 200 epochs was applied for fitting the model. To compare this model, a second DL model was generated containing 50 neurons, the he_uniform function as kernel initializer, drawing samples from a truncated normal distribution centred on 0 and the stochastic gradient descent (SGD) optimizer.

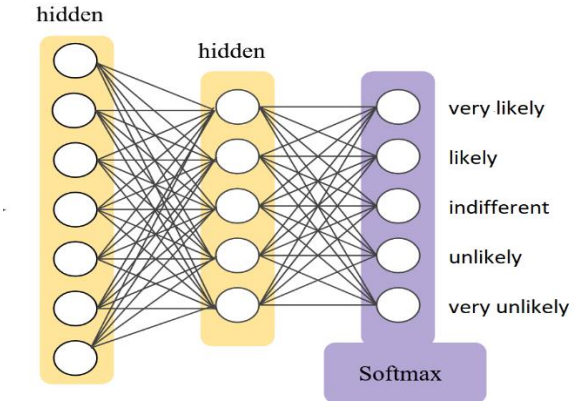


Figure 4.5: Application of Softmax on the DL model output layer

Sequential models bear the disadvantage that they only allow to provide input into the model only once at the beginning, in contrast to functional models in which layers can be connected to one another in a multi-directional way, allowing for feed-back loops (Chollet 2021). Yet, sequential models still better allow for a consideration of a large number of input parameters in comparison to a conventional regression model approaches, as currently widely used in the field of WTP/WTI. In addition, in comparison to conventional ML approaches a neural network can learn from the data in a better and more complex way and even work with unstructured data (Janiesch et al. 2021) and thus better reflect the research context. This consideration was of high importance to this research project to not directly infer findings and assumptions from studies in regions with more established insurance markets. Instead this study wants to consider a wider range of parameters to better represent the interest levels of a population that has not been widely exposed to the usage of such products before.

4.4 Results

4.4.1 Selected relevant parameters according to pairplots, correlation matrix, cross tabs

For parameter selection, feature columns for the entire data set were initially assessed for the entire data set. Then, the remaining parameters were categorized into the six thematic areas of the framework (Figure 4.1). Moreover, the grouped parameters were assessed through pairplots and a heatmap correlation matrix. As a final step of verification, crosstabs were used for assessing the correlation between the parameters and the output value. The relevant parameters reflected all six thematic areas of the presented framework on influential factors on insurance demand. As visualized in Table 4.1, parameters on potential assets to be covered were only sparsely represented in this data set, which can be seen as the reason for them only appearing once in the final selected set of parameters.

Finally, 38 parameters (including one output parameter) make up the final set of selected parameters (Table 4.3). The selected parameters of the model covered the following categories of parameters from the framework: Perception on climate change; Flood risk perception; Experienced flood impacts; (Externally defined) level of flood risk; Awareness of insurance (understanding); Trust in insurers; Perception of effectiveness of insurance; Previous insurance purchase; Insurance provider; Types of risk covered; Perceived responsibility for preventing damage; Humanitarian/public compensation; Membership in farmer's groups; Risk sharing between agents; Income; Marital status; Ability to pay; Preference uncertainty; Land status (ownership).

Table 4.3: Summary of included model parameters for assessing the demand for flood insurance

Category	Thematic area	Associated category of parameters from framework	Description of selected parameters from the survey data set
Flood risk	"Subjective" perception of flood risk	Perception on climate change	Interviewee heard of climate change before
		Flood risk perception	Perceived likelihood of future flooding
	"Objective" Flood Risk	Experienced flood impacts	Financial recovery time from commercial impacts
			Frequency of commercial impacts (past 20 years)
			Intensity of commercial impacts (past 20 years)
			Financial recovery time from all four impact types combined
			Frequency of all four impact types combined (past 20 years)
			Severity of all four impact types combined (past 20 years)
		(Externally defined) level of flood risk	Flood risk zone based on distance to the river, elevation, and reports of flood affectedness
Interaction	Interaction with insurance institutions	Awareness of insurance (understanding)	Understanding of how insurance works
			No previous insurance purchase due to lack of information
		Trust in insurers	Level of trust that insurance companies will deliver payout as promised
			No previous insurance purchase due to general lack of trust in companies
		Perception of effectiveness of insurance	Insurance as an instrument only suited for the needs of wealthy people
			No previous insurance purchase due to too much paperwork
		Previous insurance purchase	Household has access to insurance in case of experiencing flood impacts
		Insurance provider	No insurance provider/products present in the area
		Types of risk covered	Desired risk to be covered in potential flood insurance product
	Interaction with other institutions &	Perceived responsibility for preventing damage	Desiring to have access to remittances to deal with flood impacts
		Humanitarian/public compensation	Household has access to governmental support in case of experiencing flood impacts
			Household has access to NGO support in case of experiencing flood impacts

	social environment	Membership in farmer's groups	Household has access to support from cooperatives in case of experiencing flood impacts
		Risk sharing between agents	Household is member of a savings group
			Household has access to credits from banks in case of experiencing flood impacts
			Household draws upon their own resources in case of experiencing flood impacts
			Household has access to support from community solidarity funds in case of experiencing flood impacts
			Household has access to credits from savings groups in case of experiencing flood impacts
			Household has access to credits from a private lender in case of experiencing flood impacts
			Household has no access to any previously mentioned source in case of experiencing flood impacts
			Household has not bought any insurance previously because they had access to other mechanisms of coverage
Attributes	Attributes (of HH/individual)	Income	Household income per year
		Marital status	Household is female-headed
		Ability to pay	Fear that insurance purchase will affect more essential needs of the household to be covered
			Household has not bought any insurance before due to lack of means
		Preference uncertainty	Household has not bought any insurance before due to not being interested in the topic
			Uncertainty on the reason why no insurance has been purchased before
	Assets to be covered	Land status (ownership)	Household is owner of the house they are living in

4.4.2 Model accuracies

All models were applied to three separate data sets each, namely one overall data set containing submissions from both Togo and Benin (n=744) as well as two subsets from Togo (n=496) and Benin (n=248) exclusively. Initially, six machine learning models were run on the data sets and compared by their model accuracy. The applied model types for the classification are logistic regression, a histogram-based gradient boosting classifier, an optimized histogram-based gradient boosting classifier, decision trees, a bagging trees classifier, and a random forest classifier. Moreover, a sequential neural network was applied to the data sets to compare if a DL model would yield higher accuracies than the conventional ML models.

As illustrated in Table 4.4, almost all models (except for the optimized histogram-based gradient boosting classifier) returned the highest accuracies for the Togo subset. The logistic regression classifier returned an accuracy of 54.0% (stdv=0.029) for the combined data set, 48.0% (stdv=0.0042) for the Benin subset, and 61.7% (stdv=0.049) for the Togo subset. Overall, this classifier therefore ranked among the ones with the weakest performances of the conventional ML models. The histogram-based gradient boosting classifier achieved 64.0% (stdv=0.00) for the combined data set, 55.5% (stdv=0.00) for the Benin subset, and 65.3% (stdv=0.00) for the Togo subset. Thus, it ranked among the better performing conventional ML models, especially for the combined data set and the Benin subset. The model was even improved further through hyperparameter tuning and applying grid search. The model then achieved 67.0% (stdv=0.00) accuracy for the combined data set, 58% percent (stdv=0.00) for the Benin subset, which were the highest for all conventional ML models, and 69% (stdv=0.00) for the Togo subset. Moreover, a decision tree classifier was applied, which merely reached 43.7% (p=0.034) for the combined data set, 47.6% (stdv=0.051) for the Benin subset, and 53.4% (stdv=0.049) for the Togo subset. As a consequence, this classifier achieved the lowest accuracies among all conventional ML models. However, it was improved by applying bagging to then reach 61.2% (stdv=0.043) for the combined data set, 55.2% (stdv=0.035), and even 70.4% (stdv=0.041) for the Togo subset. Finally, as the last conventional ML model, a random forest classifier was applied achieving 63.6% (stdv=0.035) for the combined data set, 58.5% (stdv=0.048) for the Benin subset, and even 71.6% (stdv=0.051) for the Togo subset. These results clearly show that the datasets of Togo rendered the highest accuracies. The latter is due to the fact that there is higher correlation in the answers provided by respondents in Togo.

Since the accuracies of the conventional ML models did not yield higher accuracies (over 75-80%), two sequential neural networks from the realm of DL were applied as a comparison. The first sequential neural network model returned 100.0% of accuracy for the combined data set, as well as for the Benin

and Togo subsets. As a consequence, it yielded the best performance by far in comparison to the applied conventional ML models. This finding emerged somewhat surprising, since deep learning is rather recommended for data sets that are much larger than the survey data set. The second model however exhibited a slightly lower accuracy with 93.5% for the combined data set, 97.6% for the Benin subset and 95.12% for the Togo subset. A more detailed overview on the loss, precision, F1 score and recall are provided in Annex 15 as well as a confusion matrix in Annex 16 in the supplementary information to this article.

Table 4.4: Model accuracies of ML/DL models applied to the selected parameters

	Conventional Machine learning						Deep learning	
	Logistic Regression	Histogram-based Gradient Boosting Classifier	Optimized Histogram-based Gradient Boosting Classifier	Decision Trees	Bagging trees classifier	Random Forest Classifier	Sequential Neural Network First model	Sequential Neural Network second model
Accuracy both countries (n=744)	0.540 ± 0.029	0.64 ± 0.000	0.67 ± 0.000	0.437 ± 0.034	0.612 ± 0.045	0.636 ± 0.035	**1** ± $5.67x10^{-5}$	0.9350 ± 0.2329
Accuracy Benin subset (n=248)	0.480 ± 0.0042	0.550 ± 0.000	0.58 ± 0.000	0.476 ± 0.051	0.552 ± 0.035	0.585 ± 0.048	**1** ± 0.0013	0.9756 ± 0.1614
Accuracy Togo subset (n=496)	0.617 ± 0.049	0.653 ± 0.000	0.69 ± 0.000	0.534 ± 0.049	0.704 ± 0.041	0.716 ± 0.051	**1** ± $8.17x10^{-5}$	0.9512 ± 0.1291

4.4.3 Contribution of parameters to predicting likelihoods of insurance purchase in the deep learning model

For the sequential neural network model an overview of the most important parameters based on the feature importance value was generated (Figure 4.6). The feature importance value expresses the level of influence of a parameter on the output variable of the model (likelihood of insurance purchase). When identifying the most important features, a subset of relevant features can be selected for use in building a model. Therefore, the dimensionality is reduced as well as noise in the data. Moreover, the model interpretability is improved in that way. The selection of feature importance furthermore assists in reducing the number of parameters, therefore reducing the data and decreasing the time needed to obtain the results. The feature importance values were generated for the combined data set of both countries, as well as for the Togo and Benin subsets. In general, it

can be observed that the feature importance varies in parts to a large extent across the parameters for the individual data sets.

With regards to the parameter categories outlined by the framework presented in the study, interaction-related parameters were the most important category of parameters by far. Important parameters related to the thematic area of interaction with insurance institutions were the desired risk (agricultural, material, health, or commercial impacts) to be covered in potential flood insurance product (Togo). Also, the degree to which insurance was perceived as an instrument only suited for the needs of wealthy people (all) exhibited a high feature importance. In addition, parameters relating the interaction with other institutions and the social environment emerged as the thematic area with the most numerous important values. Feature importance was high when a household had no access to any source mentioned in the questionnaire for financial coping in case of experiencing flood impacts (all, Togo). In addition, important parameters were if a household had access to support from community solidarity funds in case of experiencing flood impacts (all), a household drawing upon their own resources to cope financially in case of experiencing flood impacts (all), and a household having access to governmental support in case of experiencing flood impacts (all).

Moreover, three further parameters achieved a high feature importance. From the parameter category of flood risk and thematic area of “objective” flood risk the financial recovery time from commercial impacts (Benin) appeared as important. Finally, from the parameter category attributes and the thematic area of attributes of HH/individuals important parameters were if a household has not bought any insurance before due to lack of means (all, Togo), and the fear that an insurance purchase will affect the ability to cover more essential needs of the household (Togo).

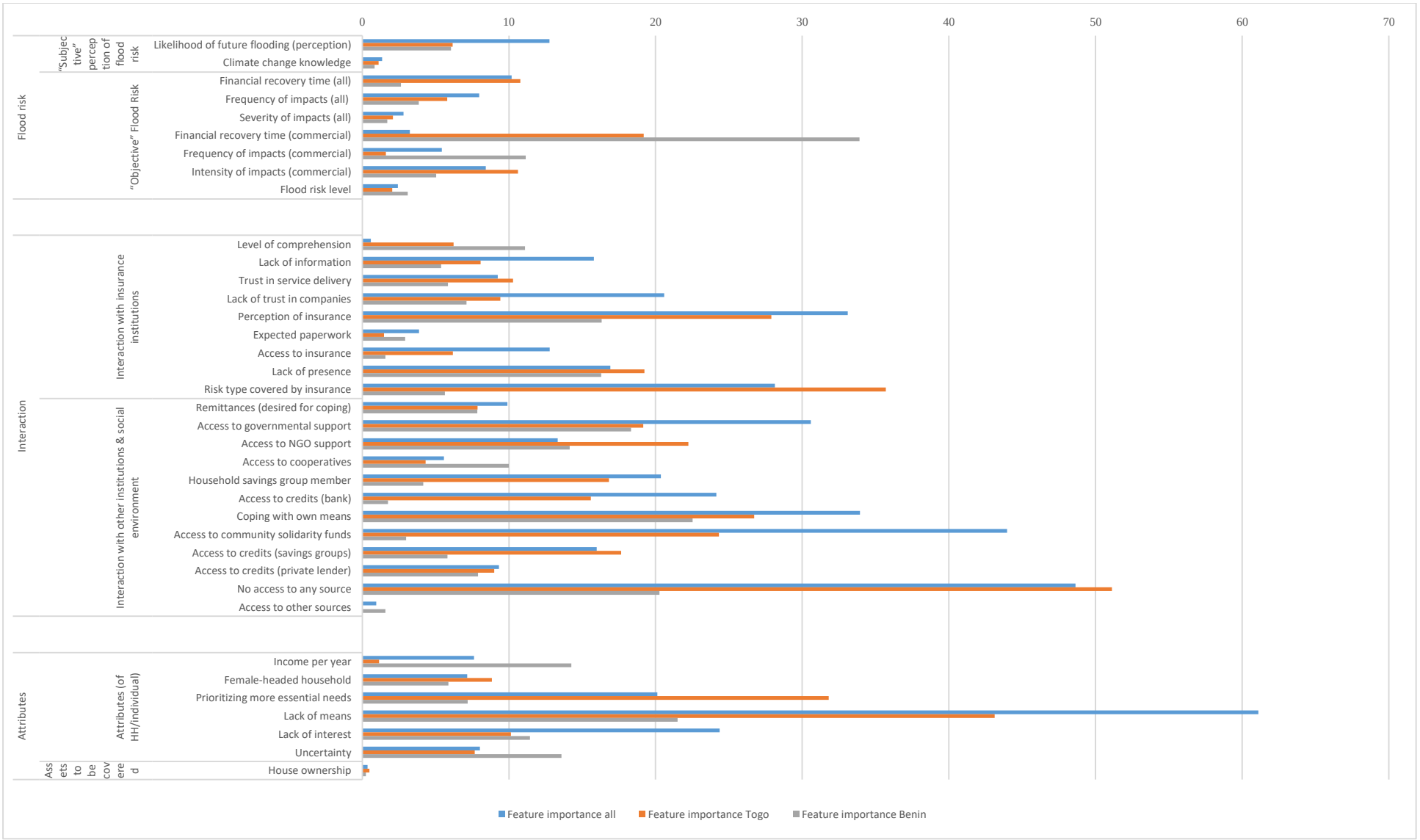


Figure 4.6: Feature importance of parameters in the sequential neural network model

4.5 Discussion

This study has enabled the consideration of a large number of parameters to research the demand for a potential flood insurance product in an area with low previous insurance exposure. To achieve this, it drew upon a data set considering manifold aspects on the household level from the areas of household characteristics and assets, experiences with floods, flood risk perception, flood impacts, financial coping mechanisms, experience with and perception of insurance, willingness to buy of a potential product. The identified parameters identified as highly important for the most accurate model type (sequential neural network model) resonate with the results of other studies. The parameters if a household has not bought any insurance before due to lack of means, and the fear that an insurance purchase will affect more essential needs of the household to be covered relate to the general aspect of the ability to pay, as also raised by Fahad and Jing (2018) and Arshad et al. (2016). Moreover, the findings that it was important if a household had no access to any source mentioned in the questionnaire, access to support from community solidarity funds, or drawing upon their own resources to cope financially in case of experiencing flood impacts, reflects the importance of risk-sharing between agents, as also pointed out by Berg et al. (2022). The aspect of having access to governmental support, was previously mentioned as humanitarian/public compensation by Seifert et al. (2013) and Botzen and van den Bergh (2012), the risk type covered by insurance by Reynaud et al. (2018), and the perception of insurance as being suited for one's needs was also raised in similar manner as the perception of effectiveness of insurance by Abbas et al. (2015). Finally, the parameter describing the financial recovery time from commercial flood impacts broadly relates to the aspect of experienced flood impacts, which has been found to be influential by a wide range of authors (Hossain et al. 2022, Osberghaus and Reif 2021, Paopid et al. 2020, Senapati 2020a, Liu et al. 2019, Fahad and Jing 2018, Reynaud et al. 2018, Arshad et al. 2016, Oulahen 2015, Atreya et al. 2015, Turner et al. 2014, Seifert et al. 2013, Hung 2009, Browne and Hoyt 2000). While those parameters have already been pointed out previously in other research contexts, this study was able to achieve a summary of parameters that could also be tested to be influential in further contexts with low previous exposure to insurance products. Also, the results indicate that interaction-related parameters play a very important role in this context.

In the field of researching the demand for flood insurance ML/DL models have not yet been applied. Even research that addresses the demand for other types of insurance is only recently picking up the use of such models. As some of the previously published studies Wanyan et al. (2022) researched the effect of air pollution on the decision to buy health insurance coupled with a deep learning method (artificial neural networks). Also, Fuino et al. (2022) used models that combine conventional statistical modeling with machine learning approaches to assess customer profiles and highlight variables that

are influential to their level of interest for long-term care insurance. Finally, Nguyen et al. (2022) compared several ML models for a case study in Vietnam and found that especially the cubist, random forest, and support vector machines models were best suited to predict the WTP for insurance for shrimp farming. Similarly, it could be of high relevance to further explore the use of ML/DL models in predicting the WTP for flood insurance addressing a regression problem to predict the monetary value of a potential product drawing upon the framework of parameters suggested by this study. Especially in a context where people have mostly not been insurance customers before, those methods enable researchers and practitioners to better pay attention to the research context without transferring a too narrow set of assumptions from other geographical research settings. In that way, the method can rather learn from the data and adjust the model to the context. Concerning Flood Risk Management in the West African context, the need for a better involvement of the targeted communities in decision-making and the design of risk-reducing measures, including insurance, has been pointed out before (Parkoo et al. 2022, Wagner et al. 2021).

Regarding the globally increasing problem of climate change, a large portion of people at risk in least-developed economies has no insurance coverage against weather-related hazardous events (InsuResilience Global Partnership 2021). In order to scale up efforts of making insurance coverage more suitable and accessible to such groups, shedding more light on their preferences and demands will help to make more meaningful progress in this area. Without such mechanisms, vulnerable communities are left too often to address the losses and damages from climate-related events, such as floods by drawing upon their own means (Amaechina et al. 2022, Wagner et al. 2022). On the one hand, it has to be borne in mind that (market-based) risk transfer instruments such as insurance are seen to be generally well-suited to address hazardous sudden-onset events, such as floods (Mechler and Deubelli 2021). On the other hand, a point of critique of insurance in the context of climate-related losses and damages is that due to the increase in severity and frequency of both slow- and sudden onset events as well as of impacts that span beyond the economic dimension the usefulness of current insurance approaches is limited (Nordlander et al. 2020). While this critique holds true it has to be borne in mind that insurance is best used in a combined and integrated manner with other risk management measures and not as a stand-alone tool (Schäfer et al. 2019). Nevertheless, it will be important to address concerns of affordability and climate justice, which could be addressed by providing subsidies to lower the premiums for an insurance product addressing flood impacts (Linnerooth-Bayer et al. 2019).

This study bears its limitations. In order to contribute even further to researching the preferences and demands of vulnerable populations with regard to insurance mechanisms, further studies could research the WTP for a potential flood insurance product in the LMRB with ML/DL models, when more

concrete forms of potential flood insurance schemes have been elaborated. In that way, coverage could eventually be raised even faster and the amount of potential subsides could be determined in a better way. Moreover, future studies could better consider parameters describing potential assets to be insured, which were not extensively represented in the data set used for this study. It could also be worth conducting studies drawing upon the framework presented in this study to already guide the data collection process and ensure coverage of all dimensions potentially relevant to flood insurance demand. Finally, the authors encourage future studies to try out additional ML models that were not yet used in this study for comparison as well as to try out other DL models, e.g. functional models.

4.6 Conclusion

This study presents a novel approach to research the demand for a potential flood insurance product by applying ML/DL models to a large number of relevant parameters. This approach was found to be especially useful for research contexts, in which people have not yet been widely exposed to insurance products. In particular, the results especially highlighted the importance of the parameters of the desired risk to be covered, perception of insurance, having no access to any source, access to support from community solidarity funds, access to governmental support, or drawing upon their own resources to cope financially, the financial recovery time (commercial impacts), no previous insurance purchase due to lack of means and the prioritization of more essential needs over purchasing insurance. In addition, the framework on relevant thematic areas of parameters provided by this study can be a useful basis for follow-up studies, using similar data-driven approaches.

4.7 References

Abbas A, Amjath-Babu TS, Kächele H, Müller K (2015) Non-structural flood risk mitigation under developing country conditions: an analysis on the determinants of willingness to pay for flood insurance in rural Pakistan. Nat Hazards 75:2119–2135. doi: 10.1007/s11069-014-1415-x

Addo IY, Danso SY (2017) Sociocultural factors and perceptions associated with voluntary and permanent relocation of flood victims: A case study of Sekondi-Takoradi Metropolis in Ghana. Jamba 9:303. doi: 10.4102/jamba.v9i1.303

Adelekan I, Fregene T (2015) Vulnerability of artisanal fishing communities to flood risks in coastal southwest Nigeria. Climate and Development 7:322–338. doi: 10.1080/17565529.2014.951011

Adelekan IO, Asiyanbi AP (2016) Flood risk perception in flood-affected communities in Lagos, Nigeria. Nat Hazards 80:445–469. doi: 10.1007/s11069-015-1977-2

Adewole IF, Agbola SB, Kasim OF (2015) Building resilience to climate change impacts after the 2011 flood disaster at the University of Ibadan, Nigeria. Environment and Urbanization 27:199–216. doi: 10.1177/0956247814547679

Adzawla W, Kudadze S, Mohammed AR, Ibrahim II (2019) Climate perceptions, farmers' willingness-to-insure farms and resilience to climate change in Northern region, Ghana. Environmental Development 32:100466. doi: 10.1016/j.envdev.2019.100466

African Risk Capacity (2021a) Africa Risk View Rapport de Mi-Saison Benin (2021)
African Risk Capacity (2021b) Africa RiskView Rapport de mi-saison Togo (2021)
Afriyie K, Ganle JK, Santos E (2018) 'The floods came and we lost everything': weather extremes and households' asset vulnerability and adaptation in rural Ghana. Climate and Development 10:259–274. doi: 10.1080/17565529.2017.1291403
Ahadzie DK, Dinye I, Dinye RD, Proverbs DG (2016) Flood risk perception, coping and management in two vulnerable communities in Kumasi, Ghana. Int. J. SAFE 6:538–549. doi: 10.2495/SAFE-V6-N3-538-549
Akoda S (2018) Le Togo, membre de l'African Risk Capacity, veut protéger ses agriculteurs des risques d'inondations. https://www.togofirst.com/fr/agro/2805-922-le-togo-membre-de-l-african-risk-capacity-veut-proteger-ses-agriculteurs-des-risques-d-inondations. Accessed 23 May 2022
Aliagha GU, Mar Iman AH, Ali HM, Kamaruddin N, Ali KN (2015) Discriminant factors of flood insurance demand for flood-hit residential properties: a case for Malaysia. J. Flood Risk Manage 8:39–51. doi: 10.1111/jfr3.12065
Aliagha UG, Jin TE, Choong WW, Nadzri Jaafar M, Ali HM (2014) Factors affecting flood insurance purchase in residential properties in Johor, Malaysia. Nat. Hazards Earth Syst. Sci. 14:3297–3310. doi: 10.5194/nhess-14-3297-2014
Amaechina EC, Anugwa IQ, Agwu AE, Ifelunini AI, Umeonuora TG, Okwor CA (2022) Assessing climate change-related losses and damages and adaptation constraints to address them: Evidence from flood-prone riverine communities in Southern Nigeria. Environmental Development 44:100780. doi: 10.1016/j.envdev.2022.100780
Amoako C, Cobbinah PB, Mensah Darkwah R (2019) Complex twist of fate: The geopolitics of flood management regimes in Accra, Ghana. Cities 89:209–217. doi: 10.1016/j.cities.2019.02.006
Arshad M, Amjath-Babu TS, Kächele H, Müller K (2016) What drives the willingness to pay for crop insurance against extreme weather events (flood and drought) in Pakistan? A hypothetical market approach. Climate and Development 8:234–244. doi: 10.1080/17565529.2015.1034232
Atreya A, Ferreira S, Michel-Kerjan E (2015) What drives households to buy flood insurance? New evidence from Georgia. Ecological Economics 117:153–161. doi: 10.1016/j.ecolecon.2015.06.024
Bagus U, Jurd de Girancourt F, Mahmood R, Manji Q (2020) Africa's insurance market is set for takeoff. https://www.mckinsey.com/featured-insights/middle-east-and-africa/africas-insurance-market-is-set-for-takeoff. Accessed 08 Dec 2022
Berg E, Blake M, Morsink K (2022) Risk sharing and the demand for insurance: Theory and experimental evidence from Ethiopia. Journal of Economic Behavior & Organization 195:236–256. doi: 10.1016/j.jebo.2021.12.035
Botzen W, van den Bergh J (2012) Risk attitudes to low-probability climate change risks: WTP for flood insurance. Journal of Economic Behavior & Organization 82:151–166. doi: 10.1016/j.jebo.2012.01.005
Botzen WW, Boer J de, Terpstra T (2013) Framing of risk and preferences for annual and multi-year flood insurance. Journal of Economic Psychology 39:357–375. doi: 10.1016/j.joep.2013.05.007
Boubacar S, Pelling M, Barcena A, Montandon R (2017) The erosive effects of small disasters on household absorptive capacity in Niamey: a nested HEA approach. Environment and Urbanization 29:33–50. doi: 10.1177/0956247816685515
Brisibe GW, Pepple TD (2018) Lessons Learnt from the 2012 Flood Disaster: Implications for Post-flood Building Design and Construction in Yenagoa, Nigeria. cea 6:171–180. doi: 10.13189/cea.2018.060307
Browne MJ, Hoyt RE (2000) The Demand for Flood Insurance: Empirical Evidence. Journal of Risk and Uncertainty 20:291–306. doi: 10.1023/A:1007823631497
Chollet F (2021) Deep Learning With Python, Second Edition, 2nd ed. Manning Publications, Greenwich, USA
Codjoe SNA, Issah AD (2016) Cultural dimension and adaptation to floods in a coastal settlement and a savannah community in Ghana. GeoJournal 81:615–624. doi: 10.1007/s10708-015-9641-7
Codjoe SNA, Owusu G, Burkett V (2014) Perception, experience, and indigenous knowledge of climate change and variability: the case of Accra, a sub-Saharan African city. Reg Environ Change 14:369–383. doi: 10.1007/s10113-013-0500-0
Darlington JC, Yiannakoulias N (2022) Experimental Evidence for Coverage Preferences in Flood Insurance. Int J Disaster Risk Sci 13:178–189. doi: 10.1007/s13753-022-00397-3
Dehm J (2020) Climate change, 'slow violence' and the indefinite deferral of responsibility for 'loss and damage'. Griffith Law Review 29:220–252. doi: 10.1080/10383441.2020.1790101
Dewi N, Kusnandar, Rahayu ES (2018) Risk mitigation of climate change impacts on rice farming through crop insurance: an analysis of farmer's willingness to participate (a case study in Karawang Regency, Indonesia). IOP Conf. Ser.: Earth Environ. Sci. 200:12059. doi: 10.1088/1755-1315/200/1/012059
Dossoumou NIP, Gnazou MDT, Villamor GB, Agbossou EK, Thiam S, Wagner S, Idrissou M (2023) Comparing households' perception of flood hazard with historical climate and hydrological data in the Lower Mono River catchment (West Africa), Benin and Togo. PLOS Climate 2(4): e0000123. https://doi.org/10.1371/journal.pclm.0000123
Enete AA, Obi JN, Ozor N, Mba CL (2016) Socioeconomic assessment of flooding among farm households in Anambra state, Nigeria. International Journal of Climate Change Strategies and Management 8:96–111. doi: 10.1108/IJCCSM-07-2014-0084

Fahad S, Jing W (2018) Evaluation of Pakistani farmers' willingness to pay for crop insurance using contingent valuation method: The case of Khyber Pakhtunkhwa province. Land Use Policy 72:570–577. doi: 10.1016/j.landusepol.2017.12.024

Feng Z, Xu C, Tao D (2018) Historical Gradient Boosting Machine. In: GCAI-2018. 4th Global Conference on Artificial Intelligence, 68-54

Flood Resilience Initiative (2020) Zurich Flood Resilience Alliance commitments and recommendations. https://www.mercycorps.org/sites/default/files/2020-02/979-PA-ZFRP-FS-UN-EVENT-V3a.pdf. Accessed 08 Dec 2022

Fuino M, Ugarte Montero A, Wagner J (2022) On the drivers of potential customers' interest in long-term care insurance: Evidence from Switzerland. Risk Manage Insurance Review 25:271–302. doi: 10.1111/rmir.12218

Gewirtzman J, Natson S, Richards J-A, Hoffmeister V, Durand A, Weikmans R, Huq S, Roberts JT (2018) Financing loss and damage: reviewing options under the Warsaw International Mechanism. Climate Policy 18:1076–1086. doi: 10.1080/14693062.2018.1450724

Giorgi F, Raffaele F, Coppola E (2019) The response of precipitation characteristics to global warming from climate projections. Earth Syst. Dynam. 10:73–89. doi: 10.5194/esd-10-73-2019

Government of the Republic of Benin (2011) Inondations au Bénin: Rapport d'evaluation des besoins post catastrophe

Government of the Republic of Benin (2020) Plan d'actions du Bénin 2020-2024 pour la mise en place du cadre national pour les services climatologiques (CNSC) du Bénin, Cotonou, Benin

Government of the Republic of Benin (2021) Projet ARCH : Le Gouvernement généralise le volet Assurance-maladie dans les communes du Bénin. https://www.gouv.bj/actualite/1145/projet-arch-gouvernement-generalise-volet-assurance-maladie-dans-communes-benin/. Accessed 26 Dec 2022

Government of the Republic of Togo (2017) Plan National d'Adaption aux Changements Climatiques du Togo (PNACC)

Hastie T, Tibshirani R, Friedman J (eds) (2009) The Elements of Statistical Learning. Springer Series in Statistics. Springer New York, New York, NY

Hossain MS, Alam GM, Fahad S, Sarker T, Moniruzzaman M, Rabbany MG (2022) Smallholder farmers' willingness to pay for flood insurance as climate change adaptation strategy in northern Bangladesh. Journal of Cleaner Production 338:130584. doi: 10.1016/j.jclepro.2022.130584

Huang C, Lubell M (2022) Household flood risk response in San Francisco Bay: linking risk information, perception, and behavior. Reg Environ Change 22. doi: 10.1007/s10113-022-01875-6

Hung H-C (2009) The attitude towards flood insurance purchase when respondents' preferences are uncertain: a fuzzy approach. Journal of Risk Research 12:239–258. doi: 10.1080/13669870802497702

InsuResilience Global Partnership (2021) Annual Report 2021. Milestones, Achievements and Progress Towards Vision 2025

James G, Witten D, Hastie T, Tibshirani R (2021) An Introduction to Statistical Learning. Springer US, New York, NY

Janiesch C, Zschech P, Heinrich K (2021) Machine learning and deep learning. Electron Markets 31:685–695. doi: 10.1007/s12525-021-00475-2

Jung A (2022) Machine Learning. Springer Nature Singapore, Singapore

Klimo M, Lukáč P, Tarábek P (2021) Deep Neural Networks Classification via Binary Error-Detecting Output Codes. Applied Sciences 11:3563. doi: 10.3390/app11083563

Kousky C (2011) Understanding the Demand for Flood Insurance. Nat. Hazards Rev. 12:96–110. doi: 10.1061/(ASCE)NH.1527-6996.0000025

Lamond J, Adekola O, Adelekan I, Eze B, Ujoh F (2019) Information for Adaptation and Response to Flooding, Multi-Stakeholder Perspectives in Nigeria. Climate 7:46. doi: 10.3390/cli7040046

Léger T (2022) Insurers need to step up to close the flood protection gap. https://www.swissre.com/risk-knowledge/risk-perspectives-blog/insurers-step-up-to-close-flood-protection-gap.html. Accessed 08 Dec 2022

Levy PS, Lemeshow S (2008) Sampling of Populations: Methods and Applications, 4th Edition. John Wiley & Sons, Inc., Hoboken, NJ, USA

Linnerooth-Bayer J, Surminski S, Bouwer LM, Noy I, Mechler R (2019) Insurance as a Response to Loss and Damage? In: Mechler R, Bouwer LM, Schinko T, Surminski S, Linnerooth-Bayer J (eds) Loss and Damage from Climate Change. Springer International Publishing, Cham, pp 483–512

Liu X, Tang Y, Ge J, Miranda MJ (2019) Does experience with natural disasters affect willingness-to-pay for weather index insurance? Evidence from China. International Journal of Disaster Risk Reduction 33:33–43. doi: 10.1016/j.ijdrr.2018.09.006

Lloyd's (2018) A world at risk. Closing the insurance gap

Lo AY (2013) Household Preference and Financial Commitment to Flood Insurance in South-East Queensland. Australian Economic Review 46:160–175. doi: 10.1111/j.1467-8462.2013.12009.x

Mechler R, Deubelli TM (2021) Finance for Loss and Damage: a comprehensive risk analytical approach. Current Opinion in Environmental Sustainability 50:185–196. doi: 10.1016/j.cosust.2021.03.012

Meton A (2019) Gestion des risques et catastrophes: L'assurance comme une priorité, selon le professeur Théodore Adjakpa. https://lanation.bj/gestion-des-risques-et-catastrophes-lassurance-comme-une-priorite-selon-le-professeur-theodore-adjakpa/. Accessed 26 Dec 2022

Navrud S, Vondolia GK (2020) Farmers' preferences for reductions in flood risk under monetary and non-monetary payment modes. Water Resources and Economics 30:100151. doi: 10.1016/j.wre.2019.100151

Netusil NR, Kousky C, Neupane S, Daniel W, Kunreuther H (2021) The Willingness to Pay for Flood Insurance. Land Economics 97:17–38. doi: 10.3368/wple.97.1.110819-0160R1

Nguyen KAT, Nguyen TAT, Nguelifack BM, Jolly CM (2022) Machine Learning Approaches for Predicting Willingness to Pay for Shrimp Insurance in Vietnam. Marine Resource Economics 37:155–182. doi: 10.1086/718835

Nordlander L, Pill M, Romera BM (2020) Insurance schemes for loss and damage: fools' gold? Climate Policy 20:704–714. doi: 10.1080/14693062.2019.1671163

Oduniyi OS, Antwi MA, Tekana SS (2020) Farmers' Willingness to Pay for Index-Based Livestock Insurance in the North West of South Africa. Climate 8:47. doi: 10.3390/cli8030047

Osberghaus D, Reif C (2021) How do different compensation schemes and loss experience affect insurance decisions? Experimental evidence from two independent and heterogeneous samples. Ecological Economics 187:107087. doi: 10.1016/j.ecolecon.2021.107087

Oulahen G (2015) Flood insurance in Canada: implications for flood management and residential vulnerability to flood hazards. Environ Manage 55:603–615. doi: 10.1007/s00267-014-0416-6

Paopid S, Tang J, Leelawat N (eds) (2020) Willingness to pay for flood insurance: a case study in Phang Khon, Sakon Nakhon Province, Thailand. IOP Conference Series: Earth and Environmental Science

Parkoo EN, Thiam S, Adjonou K, Kokou K, Verleysdonk S, Adounkpe JG, Villamor GB (2022) Comparing Expert and Local Community Perspectives on Flood Management in the Lower Mono River Catchment, Togo and Benin. Water 14:1536. doi: 10.3390/w14101536

Pill M (2022) Towards a funding mechanism for loss and damage from climate change impacts. Climate Risk Management 35:100391. doi: 10.1016/j.crm.2021.100391

Ranasinghe R, Ruane AC, Vautard R, Arnell N, Coppola E, Cruz FA, Dessai S, Islam AS, Rahimi M, Ruiz D (2021) Climate Change Information for Regional Impact and for Risk Assessment. In: Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis MI, Huang M, Leitzell K, Lonnoy E, Matthews J, Maycock TK, Waterfield T, Yelekçi O, Yu R, Zhou B (eds) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 1767–1926

Ren J, Wang HH (2016) Rural Homeowners' Willingness to Buy Flood Insurance. Emerging Markets Finance and Trade 52:1156–1166. doi: 10.1080/1540496X.2015.1134867

Reynaud A, Nguyen M-H, Aubert C (2018) Is there a demand for flood insurance in Vietnam? Results from a choice experiment. Environ Econ Policy Stud 20:593–617. doi: 10.1007/s10018-017-0207-4

Robinson PJ, Botzen W (2020) Flood insurance demand and probability weighting: The influences of regret, worry, locus of control and the threshold of concern heuristic. Water Resources and Economics 30:100144. doi: 10.1016/j.wre.2019.100144

Robinson PJ, Botzen WJW (2019) Determinants of Probability Neglect and Risk Attitudes for Disaster Risk: An Online Experimental Study of Flood Insurance Demand among Homeowners. Risk Anal 39:2514–2527. doi: 10.1111/risa.13361

Schäfer L, Warner K, Kreft S (2019) Exploring and Managing Adaptation Frontiers with Climate Risk Insurance. In: Mechler R, Bouwer LM, Schinko T, Surminski S, Linnerooth-Bayer J (eds) Loss and Damage from Climate Change. Springer International Publishing, Cham, pp 317–341

Seifert I, Botzen WJW, Kreibich H, Aerts JCJH (2013) Influence of flood risk characteristics on flood insurance demand: a comparison between Germany and the Netherlands. Nat. Hazards Earth Syst. Sci. 13:1691–1705. doi: 10.5194/nhess-13-1691-2013

Senapati AK (2020a) Do Farmers Value Insurance Against Extreme Droughts and Floods? Evidence from Odisha, India. Global Business Review:097215092095761. doi: 10.1177/0972150920957616

Senapati AK (2020b) Insuring against climatic shocks: Evidence on farm households' willingness to pay for rainfall insurance product in rural India. International Journal of Disaster Risk Reduction 42:101351. doi: 10.1016/j.ijdrr.2019.101351

Sidi P, Mamat MB, Sukono, Supian S, Putra AS (2018) Demand analysis of flood insurance by using logistic regression model and genetic algorithm. IOP Conf. Ser.: Mater. Sci. Eng. 332:12053. doi: 10.1088/1757-899X/332/1/012053

Thistlethwaite J, Henstra D, Brown C, Scott D (2020) Barriers to Insurance as a Flood Risk Management Tool: Evidence from a Survey of Property Owners. Int J Disaster Risk Sci 11:263–273. doi: 10.1007/s13753-020-00272-z

Trisos CH, Adelekan IO, Totin E, Ayanlade A, Efitre J, Gemeda A, Kalaba K, Lennard C, Masao C, Mgaya Y (2022) Africa. In: Pörtner H-O, Roberts DC, Tignor M, Poloczanska ES, Mintenbeck K, Alegría A, Craig M, Langsdorf S, Löschke S, Möller V, Okem A, Rama B (eds) Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II

to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 1285–1455

Turner G, Said F, Afzal U (2014) Microinsurance Demand After a Rare Flood Event: Evidence From a Field Experiment in Pakistan. Geneva Pap Risk Insur Issues Pract 39:201–223. doi: 10.1057/gpp.2014.8

Wagner S, Souvignet M, Walz Y, Balogun K, Komi K, Kreft S, Rhyner J (2021) When does risk become residual? A systematic review of research on flood risk management in West Africa. Reg Environ Change 21:84. doi: 10.1007/s10113-021-01826-7

Wagner S, Thiam S, Dossoumou NIP, Hagenlocher M, Souvignet M, Rhyner J (2022) Recovering from Financial Implications of Flood Impacts—The Role of Risk Transfer in the West African Context. Sustainability 14:8433. doi: 10.3390/su14148433

Wanyan R, Yang L, Pu M, Zhao T, Zeng L (2022) The Nexus Between Air Pollution and Life Insurance Demand in China: Evidence from Deep Machine Learning. In: Sun X, Zhang X, Xia Z, Bertino E (eds) Advances in Artificial Intelligence and Security, vol 1586. Springer International Publishing, Cham, pp 524–539

5. Research conclusions and implications for future research and policy-making concerning the potential role of insurance in flood risk management in the Lower Mono River basin

In this section of the dissertation, the main conclusions from the literature review and empirical research are outlined in relation to the initially presented research questions (compare with section 1.3). Moreover, the section presents recommendations for future directions of similar research as well as for policy makers in the field of flood risk management in the West African region. Those recommendations are formulated with the aim of helping to reduce the impact of floods on households at risk in the research area, in particular regarding the financial implications they have on them. Hopefully through this, this project can contribute to a better foundation for decision-makers to create suitable risk transfer mechanisms that properly help in mitigating the impacts on the population.

5.1 Research conclusions

In this research project, the central research objective is to explore the potential role of insurance as a flood risk management strategy for at risk-households in the Lower Mono River basin area shared between Togo and Benin, West Africa. To achieve this objective, academic literature from the West African region was systematically reviewed, two workshops with 26 stakeholders from both countries were conducted, 16 semi-structured interviews with flood-affected household members were held, and household survey data was collected from 744 households in 24 villages. Lessons for the role of a potential insurance mechanism in the LMRB from existing research occupied with flood risk management in the West African region were drawn by applying a systematic literature review approach. In addition, those insights were complemented by workshops and semi-structured interviews, in particular regarding the types of flood impacts that households in the area are experiencing. Moreover, the prevalence and sufficiency of existing risk transfer mechanisms that are available to at risk households for addressing financial flood impacts was investigated through the initial insights of the workshops and semi-structured interviews. Also, data from the household survey relating to different types of flood impacts with financial implications was analyzed by applying a Principal Component Analysis (PCA) and a Generalized Linear Model (GLM). Finally, the explicit demand for a potential flood insurance product by at risk households in the research area was analyzed by selecting relevant variables through a combination of feature columns, pairplots, correlation heatmap matrix as well as crosstabs. Subsequently, deep learning models (sequential neural networks) were developed, which were then compared to various machine learning approaches (K-nearest neighbor classifier, gradient boosting classifier, decision trees, random forest

model). The following sub-chapters refer to research conclusions that can be drawn from each research article respectively. In that sense sub-section 5.1.1 refers to chapter 2 (literature review), sub-section 5.1.2 to chapter 3 (first empirical research paper), and 5.1.3 to chapter 4 (second empirical research paper).

5.1.1 Which lessons can be drawn from research trends in the management of common flood impacts in the West African context for the role of a potential insurance mechanism in the Lower Mono River basin for targeted households?

It can be concluded that the following research trends regarding practiced flood risk management in the West African region are relevant to this research project. On the one hand, the study looked at flood risk management measures that were applied before the most recent flood event reported in the analyzed case studies. There, it became apparent that infrastructural measures were the most frequently applied measure before a reported flood event in a case study took place, especially drainage construction in urban areas, reflecting the necessity of amending the consequences of unplanned urban growth from the past decades. However, this finding is also unveiling the strength of a flood control approach in the area, viewing floods as a problem that can be mainly contained by engineered solutions. This finding also implies that measures from the realms of prevention, preparedness and risk transfer were less represented and only played a subordinate role. On the other hand, risk management measures applied after the most recent flood event mentioned in case studies were summarized. Also there, infrastructural interventions in the form of retrofit drainage channel constructions were very prevalent together with temporary relocation activities. However, support activities from the social environment appeared most prominently - giving an important indication on the importance of mutual help after floods in the research area. This finding also led the way for the empirical investigation of the means that are available to households at risk in the research area (second publication), since it did not become sufficiently clear in the review whether such support activities would also extend to providing financial assistance for each other.

Furthermore, the most frequently mentioned aspect in terms of recommended activities to continuously reduce levels of residual flood risk in case studies was the realm of policies, especially for FRM stakeholders to better collaborate and for groups at risk to be better involved in decision-making processes. This lack of involvement of the population in FRM decision-making, among other aspects, also reflects in them currently not having sufficient options for risk transfer available that would allow for adequate financial protection against the financial implications of flood impacts. Interestingly, insurance appeared as one of the most frequently recommended measure, further

underscoring the gap of financial instruments to deal with flood impacts. Nonetheless, the reviewed studies actually did not provide further information on the feasibility of flood insurance in the West African research context, which portrayed additional motivation for this research project to shed more light on this aspect. Other interesting findings from investigating the recommended FRM measures were that again infrastructural measures, such as drainage construction or improvement ranked fairly high as well as activities aiming at awareness-raising and sensitization to flood risk. Especially the latter seems to have been neglected in the currently dominant flood control approach, seeing the population at risk rather as rather having to be managed and less as active agents that can play a significant role in the FRM process and thus in being involved more in prevention, preparedness and risk transfer.

In addition, the literature review investigated the types of impacts that are commonly arising from floods in the West African region. It was found that material damages, such as damaged buildings and possessions/goods are by far the most frequent type of flood impact reported in case studies. In addition, health impacts, such as fatalities but also the spreading of sickness and diseases was mentioned as a common type of flood impact. Aside that, the loss of income and livelihood sources stood out as a frequent impact type mentioned in case studies. The variety of common impact types showcases that floods affect the population at risk in diverse ways and that FRM and a potential insurance approach need to pay attention to those dimensions in which risk needs to be managed. Those findings also provided indications to further investigate in which ways – directly or indirectly – floods exactly affect households financially in the research area (following section).

5.1.2 What is the prevalence and sufficiency of existing risk transfer mechanisms that are available to at risk households for addressing financial flood impacts?

In order to assess the prevalence and sufficiency of existing risk transfer mechanisms it was important to the research project to previously explore more in-depth in which ways floods affect households financially. In the empirical research part of the project it was found through workshops and semi-structured interviews that flood impacts with financial implications could be distinguished into four broader categories for the context of the research area: Agricultural damage (particularly the loss and destruction of crops and plantations); Material damages (particularly the damage or destruction of houses); health impacts (raising the likelihood of falling ill with malaria, diarrhea, or sore feet by walking through the flood waters, particularly for children and the subsequent payment for medication or medical treatment); and trade impacts (by damaging stored agricultural or other manufactured products and inaccessible or destroyed markets). In theory, those different impact

types would provide sufficient insurable interest for a potential flood insurance mechanism in the research area.

Nonetheless, when looking at how frequent and how severe those flood impacts with financial impacts occur on average, it became clear that existing risk transfer mechanisms could easily be overwhelmed and that conventional (market-based) insurance approaches seem currently unfeasible without the implementation of measures that significantly reduces the magnitude and frequency of flood impacts. When being asked in the household survey about to what extent they were affected by the four identified types of flood impacts in the past 20 years on average, major shares of the respondents stated to be at least affected once per year in at least medium frequency for agricultural (75.26%), material (49.27%), health (65.08%), and trade impacts (55.59%).

When asking households about the financial coping mechanisms they have access to for mitigating the financial implications of flood impacts it became apparent that currently insurance only plays a minor role (2.9%). Contrarily, respondents frequently mentioned to be using their own resources (47.2%), receiving relief aid from governmental agencies (37.8%) or from NGOs (30.2%). Besides, also mechanisms that are closer to the communities such as cooperatives (24.8%) and credits obtained from savings groups (23.6%) played a relevant role for a certain number of interviewed households. Remarkably, it was also those two latter mechanisms that were significantly associated with a shortened financial recovery time, as shown by the GLM model, which points towards the importance and relevance of such mechanisms that are close to the communities in the basin. However, it could also reflect a tendency that those mechanisms mostly get drawn upon in cases of lower impact severity. In that case it would bring up the assumption that the capacity of such small scale risk pools is overwhelmed in situations of higher impact severity. Out of the existing financial coping mechanisms available to the households, insurance, credits from savings groups, remittances and community solidarity funds were classified as either formal or informal risk transfer. Also, when looking at the financial recovery time alone for all four impact types it became clear that a large number of interviewed households takes more than a half year to recover from the financial implications while some even indicated to never recover fully. Thus, it seems a necessity to pursue the establishment of further, widely accessible risk transfer mechanisms. However, it will be also indispensable to reduce current flood risk levels significantly in case of seeking to establish a flood insurance mechanism.

5.1.3 What is the explicit demand for a potential flood insurance product by at risk households in the research area?

The explicit demand for insurance among the interviewed population in the basin was researched based on the household survey data set. Since the data set did not contain many parameters representing information on potential assets to be insured, only one parameter from this category reflected in the finally selected set of variables for the models. Nevertheless, the proposed framework for parameter selection proved to be a highly valuable contribution of the study. It will be helpful in guiding the data collection of future studies focusing on research insurance demand in settings with low previous insurance exposure with ML/DL models. The final set of parameters used in the models, selected based on feature columns, pair plots, a correlation matrix and crosstabs, contains the following parameters: Perception on climate change; Flood risk perception; Experienced flood impacts; (Externally defined) level of flood risk; Awareness of insurance (understanding); Trust in insurers; Perception of effectiveness of insurance; Previous insurance purchase; Insurance provider; Types of risk covered; Perceived responsibility for preventing damage; Humanitarian/public compensation; Membership in farmer's groups; Risk sharing between agents; Income; Household being female-headed; Ability to pay; Preference uncertainty, Land status (ownership).

When comparing the model accuracies of several ML/DL approaches (logistic regression, histogram-based gradient boosting classifier, optimized histogram-based gradient boosting classifier, decision trees, bagging trees, random forest, and two sequential neural networks) it was discovered that the DL models outperformed all ML models (with 100% accuracy for the combined data set, as well as for the Benin and the Togo subset). Also, certain parameters showed as highly important for the different levels of flood insurance purchase likelihood: The desired risk to be covered, perception of insurance, having no access to any source, access to support from community solidarity funds, access to governmental support, or drawing upon their own resources to cope financially, the financial recovery time (commercial impacts), no previous insurance purchase due to lack of means and the prioritization of more essential needs over purchasing insurance. Overall, the results portray an elevated importance of parameters that relate to the interaction with insurance institutions as well as other institutions and the social environment, since the appeared more numerous and with higher importance in the final set of selected parameters, as compared to parameters from the areas of flood risk and household attributes. Furthermore, this study showcases the added value of considering a wider range of parameters from the research context, especially considering the low previous exposure of households to insurance products.

5.2 Recommendations

Beyond the conclusions outlined above that can be directly derived from the research conducted in this project, a number of recommendations that are relevant to both policy-makers/decision-makers and researchers concerned with FRM will be presented in this section. Parts of both the policy and research recommendations have been shared in an earlier discussion paper targeted at stakeholders engaging in flood risk management and risk transfer in the research context (Wagner 2022). This section presents an updated version of those recommendations that have also been complemented by further findings that emerged from the dissertation research.

5.2.1 Policy recommendations

Investment into effective adaptation measures to improve the insurability of flood risks: Firstly, this research project found that there is a high need for some better form of coverage against flood impacts, in particular focusing on those that have financial implications for the households at risk. However, it was also found that the current frequency and severity levels of impacts are too high to allow for a conventional (market-based) insurance mechanism to be financially viable. Therefore, it is essential for decision-/policy-makers to implement adaptation measures that significantly reduce current risk levels. Doing that will enable insurance companies to offer coverage for the residual risk of low frequency/high severity events that can still occur after the implementation of effective risk management measures. In order to leverage additional financing for adaptation measures in the basin, insurance companies could be involved as financing bodies since it would open up a potential flood insurance market for them by creating better conditions for the insurability of flood risks in the LMRB. The latter aspect could be especially relevant to Togolese insurance companies, given the relatively higher willingness to insure in the Togolese part of basin. While working on improving the conditions of insurability in the LMRB, it could also be of high relevance to extend social protection schemes to also cover, at least in parts, for flood impacts, by involving existing commitments of both countries such as for example the African Risk Capacity (ARC). In addition, highly polluting nations, public institutions and insurance companies could jointly engage in financing a fund that is targeted at supporting activities from the realm of prevention to continuously reduce flood risk further from the onset. Those conclusions are similar to Wagner (2022).

Supporting and complementing of existing local financial coping mechanisms: The research showed that floods continuously set back households in their financial achievements and therefore expose the insufficiency and unsustainability of current, locally existing financial coping mechanisms. On the one hand, it could be shown that local mechanisms such as access to support from cooperatives and credits

from savings groups were significantly associated with a shortened recovery time and are thus relevant actors in the financial recovery process. On the other hand, it was also found that none of those groups was actually formed to assist in times of when households experience flood impacts and them being used for that purpose sets back their financial achievements. This research project recommends to governmental agencies, actors of development cooperation/NGOs and insurance companies to support and complement such locally existing mechanisms (in particular cooperatives and savings groups) and a potential insurance mechanism could presumably create ties to those groups as possible aggregators and contact points to communities, since the population in the LMRB is widely familiar with them and they achieved a relatively wide reach. Besides, it could be explored if a potential insurance product could couple insurance with a savings product on the group level, e.g. for savings groups or cooperatives and whether further activities that contribute to the reduction of flood risk could be fostered through those groups. Those conclusions are similar to Wagner (2022).

Raising access to information and engaging in trust-building activities with communities: This research project has shown that the access to information, trust and proper understanding of the functioning of insurance are crucial to the willingness to insure among the households in the LMRB. To address those aspects, it can be helpful to create relationships with the already established mechanisms of financial coping mentioned above (e.g., savings groups and cooperatives) in order to reach communities better with a potential risk transfer product that is tailor-made to their needs. In parallel, awareness-raising activities on the general understanding of insurance products will be a crucial component in case of rolling out a flood insurance product to cultivate trust levels. Moreover, this will ensure that new clients have realistic expectations towards the level of protection that a potential product can provide. Those conclusions are similar to Wagner (2022).

Consideration of interaction-related aspects for insurance-related flood risk management activities: The study on the influential factors on insurance purchase has shown that factors that relate to either interaction with insurance institutions or other institutions and the social environment have played an important role in influencing the willingness to purchase a potential flood insurance product in the observed case study. Especially if people had no access to any source for financial coping or if they had access to community solidarity funds played an important role in influencing insurance demand. Also, the way in which insurance as perceived as suited to one's financial status as well as the type of risk (agricultural, material, health, or commercial impacts) supposed to be covered in a potential product played an important role in influencing insurance demand. While the perceived lack of means also had high importance in influencing insurance demand, other variables from the areas of flood risk and household attributes did not reach comparable levels of importance and were also not represented as numerously in the final selected set of parameters. Future flood insurance roll out

campaigns should be aware of the importance of interaction-related aspects and ensure to address the underlying concerns

Better involvement of citizens in flood risk management aiming at prevention and preparedness: The current flood risk management paradigm both in the West African region and in the LMRB points towards a flood control approach as well as a focus on disaster response. Instead, activities focused on prevention and preparedness are receiving less attention. In addition, local efforts of risk reduction seem to take place in an isolated manner and could be supported through a coherent, basin-wide approach that coordinates and complements existing activities in a subsidiary manner.

5.2.2 Research recommendations

Research on effective flood adaptation measures: A valuable further contribution of research could be to generate reliable recommendations on effective, long term flood adaptation measures. It will be crucial to elaborate such recommendations by working closely with the communities in the LMRB to ensure the level of acceptance of adaptation measures among the population as well as to achieve a more participatory way of FRM in the research area. Research could also focus on the locally existing capacities of agencies and actors to implement adaptation measures and suggest opportunities for development cooperation from highly polluting nations to complement and strengthen their implementation. In light of the L&D debate, such support could help to achieve a more equitable approach.

Research on levels of access to and equity within existing groups of financial coping: Further research might attempt to also clarify if existing options of financial coping, in particular informal risk transfer, are accessible to all community members or if there are restrictions to accessing them for certain groups in society (e.g., based on gender, income, occupation, social status, etc.). It could also be highly relevant to shed more light on the conditions that such arrangements commonly apply in order to grant financial support to their members during the recovery process. Besides, research could explore if the groups are equitable on their members or if some of them have to carry a disproportionate burden in covering the impacts of their members. Those conclusions are similar to Wagner (2022).

Research on previous experiences with insurance and the institutional environment: It could prove helpful to conduct (qualitative) follow-up studies on the experiences that residents of the basin made with insurance products as well as on their entanglements in local risk-sharing practices. Such studies could help to better understand the observed importance of interaction-related variables in insurance demand for a potential product. In addition, the institutional enabling environment for insurance

could receive more attention from research to explore further hurdles that could hinder the establishment of insurance beyond the risk levels and the willingness to insure.

Research on the willingness to pay relating to a concretely shaped product: This research project focused on clarifying the general interest level of the flood-affected population in the basin towards a potential flood insurance product. Further research could complement this endeavor by concentrating on determining the willingness to pay for a concretely shaped product. This aspect was deliberately left open in this research project to gauge the general interest level and to not generate false expectations among the interviewed households, with regards to the unlikelihood of a flood insurance product being established in the near future. Regarding the expressed preferences of interviewed households, such a product could primarily focus on covering agricultural impacts. However, as previously mentioned, the pursuit of establishing such a product might merely be advisable after the establishment of effective adaptation options.

In-depth research on the relationship between agricultural dependency and financial recovery time: The research project yielded an additional remarkable aspect that emerged from the empirical research on factors influencing the financial recovery time. The GLM model revealed that an increasing agricultural dependency was significantly associated with a shortened financial recovery time. Further research could try to concentrate on clarifying if people who rely more on agriculture can quickly recover in a rural setting due to the level of diversification of agricultural activities in comparison to for example service- or retail-related businesses.

5.3 References

Wagner S (2022) The potential role of Insurance in flood adaptation – A case study of the transboundary Lower Mono River Basin (LMRB) shared between Togo and Benin. MCII Discussion Paper Series August 2022. https://climate-insurance.org/wp-content/uploads/2022/11/MCII_set_of_conclusions_FINAL_Nov-22.pdf. Accessed 22 Mar 2023

6. Summary

6.1 English summary

The Lower Mono River basin (LMRB) located both in Togo and Benin is confronted with challenges such as periodic flooding, infrastructural development, deforestation, settlement expansion, land use change and risk governance. The basin is largely rural and characterized by various small-sized village settlements whose livelihoods are largely dependent on agriculture. The population is regularly affected by floods and experiences a diverse range of impacts. A large part of the households is affected financially, requiring monetary resources to cope with the impacts. However, risk transfer mechanisms that would allow the households to formally shift the consequences of those impacts to another party are still widely absent. In order to address this gap in financial protection, the feasibility of a potential flood insurance mechanism for the research area for at risk-households in the LMRB is assessed through researching the following questions: (1) Which lessons can be drawn from research trends in the management of common flood impacts in the West African context for the role of a potential insurance mechanism in the LMRB for targeted households? Support activities from the social environment appeared most prominently after a disastrous flood event. In addition, insurance appeared as one of the most frequently recommended measure, further underscoring the gap of financial instruments to deal with flood impacts. Nonetheless, the studies under review did not conduct research on the feasibility of flood insurance. (2) What is the prevalence and sufficiency of existing risk transfer mechanisms that are available to at risk households for addressing financial flood impacts? The frequency and severity of flood impacts with financial implications could easily overwhelm existing risk transfer mechanisms and conventional insurance approaches seem currently unfeasible without the implementation of effective adaptation measures. Support from cooperatives and credits obtained from savings groups were significantly associated with a shortened financial recovery time, as shown by the GLM model. (3) What is the explicit demand for a potential flood insurance product by at risk households in the research area? ML models were applied to a set of parameters selected through a data-driven process and a guiding framework with six thematic areas. Among the applied models, sequential neural networks yielded the highest accuracy. It became apparent that parameters from the area of either interaction with insurance institutions as well as interaction with other institutions and the social environment reflected more prominently and with higher importance than parameters from the areas of flood risk or household attributes.

6.2 Deutsche Zusammenfassung

Das Einzugsgebiet des unteren Mono-Flusses (LMRB) in Togo und Benin ist mit Herausforderungen wie regelmäßigen Überschwemmungen, Infrastrukturentwicklung, Entwaldung, Siedlungsexpansion, Landnutzungsänderungen und Risiko-Governance konfrontiert. Das Einzugsgebiet ist größtenteils ländlich geprägt sowie von kleineren dörflichen Siedlungen, deren Lebensunterhalt weitgehend von der Landwirtschaft abhängt. Die Bevölkerung ist regelmäßig von Überschwemmungen betroffen und erfährt eine Vielzahl von Auswirkungen. Ein Großteil der Haushalte ist finanziell betroffen und benötigt monetäre Mittel, um die Auswirkungen zu bewältigen. Mechanismen für den Risikotransfer, die es den Haushalten ermöglichen, die Folgen dieser Auswirkungen formell auf eine andere Partei abzuwälzen, sind jedoch noch weithin nicht vorhanden. Um diese Lücke in der finanziellen Absicherung zu schließen, wird die Durchführbarkeit eines potenziellen Hochwasserversicherungsmechanismus für das Forschungsgebiet für gefährdete Haushalte im LMRB durch die folgenden Fragen bewertet: (1) Welche Lehren können aus den Forschungstrends bei der Bewältigung allgemeiner Überschwemmungsfolgen im westafrikanischen Kontext für die Rolle eines potenziellen Versicherungsmechanismus im LMRB für die betroffenen Haushalte gezogen werden? Hilfe aus dem sozialen Umfeld trat nach einem katastrophalen Hochwasserereignis am deutlichsten hervor. Darüber hinaus gehörte die Versicherung zu den am häufigsten empfohlenen Maßnahmen, was die Lücke bei den Finanzinstrumenten zur Bewältigung der Hochwasserfolgen weiter verdeutlicht. Die untersuchten Studien vertieften jedoch nicht die Durchführbarkeit von Hochwasserversicherungen. (2) Wie verbreitet und ausreichend sind die bestehenden Risikotransfermechanismen, die den gefährdeten Haushalten zur Bewältigung der finanziellen Hochwasserfolgen zur Verfügung stehen? Die Häufigkeit und Schwere von Schäden durch Überschwemmungen mit finanziellen Auswirkungen könnten die bestehenden Risikotransfermechanismen überfordern, und herkömmliche Versicherungsansätze scheinen derzeit ohne die Umsetzung wirksamer Anpassungsmaßnahmen nicht realisierbar zu sein. Die Unterstützung durch Genossenschaften und Kredite von Spargruppen waren im GLM-Modell signifikant mit einer verkürzten finanziellen Erholungszeit assoziiert. (3) Wie hoch ist die explizite Nachfrage nach einem potenziellen Hochwasserversicherungsprodukt durch gefährdete Haushalte im Untersuchungsgebiet? ML-Modelle wurden auf Parameter angewandt, die durch einen datengesteuerten Prozess und einen Leitrahmen mit sechs thematischen Bereichen ausgewählt wurden. Unter den angewandten Modellen erbrachten sequentielle neuronale Netze die höchste Genauigkeit. Es zeigte sich, dass sich Parameter aus dem Bereich der Interaktion mit Versicherungsinstitutionen sowie mit anderen Institutionen und dem sozialen Umfeld mit höherer Bedeutung widerspiegelten als Parameter aus den Bereichen Hochwasserrisiko oder Haushaltsmerkmale.

7. Annex

7.1 Annex for "When does risk become residual? - A systematic review of research on flood risk management in West Africa"

Annex 1 Search terms used in Web of Knowledge, Scopus, and African Journals Online (AJOL)

Web of Knowledge: (TS=(flood* OR *inond* OR inundat* OR crue*) AND TS=(*risk* OR risque* OR residual OR résiduel* OR management OR gestion OR vulnerab* OR vulnérab* OR adapt* OR resilien* OR résilien* OR cop* OR "faire face" OR mitigat* OR atténu* OR reduc* OR réduc* OR impact* OR loss* OR perte$ OR damage$ OR dégâts OR respon* OR répon* OR disast* OR catastroph* OR capacit* OR protect* OR warn* OR alert* OR transfer OR transfert OR retention OR rétention OR insur* OR assur* OR reinsur* OR réassur* OR remittance* OR versement* OR aid$ OR help* OR mutu?l* OR gift* OR cadeau* OR shar* or partag* OR cr?dit* OR fund* OR fonds OR r?serve$ OR saving* OR économi* OR income$ OR revenu$ OR poverty OR poor* OR pauvre* OR livelihood$ OR subsistence OR agricultur* OR bank$ OR banque$ OR government* OR gouvernement* OR famil* OR commun* OR network$ OR réseau$) AND TS=("west* africa*" OR "afrique de l'ouest" OR "ouest-africain*" OR benin* OR bénin* OR togo* OR senegal* OR sénégal* OR gambia* OR gambie* OR guinea* OR guinée* OR "guinea-bissau*" OR "guinée-bissau*" OR "bissau-guinéen*" OR mali* OR "ivory coast" OR ivorian* OR "côte d'ivoire" OR ivoirien* OR "sierra leone*" OR "sierra léon*" OR "burkina faso" OR burkinab* OR niger* OR nigér* OR nigeria* OR nigéria* OR ghan* OR liberia* OR libérien* OR "cap-ver*" OR "cape verd*") NOT TS=(malicious OR malignant OR "Papua New Guinea" OR attack*)) AND LANGUAGE: (English OR French) AND DOCUMENT TYPES: (Article OR Book Chapter) Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan=1991-2019-> **1,222 documents**

Scopus: TITLE-ABS-KEY (flood* OR *inond* OR inundat* OR crue*) AND TITLE-ABS-KEY (*risk* OR risque* OR residual OR résiduel* OR management OR gestion OR vulnerab* OR vulnérab* OR adapt* OR resilien* OR résilien* OR cop* OR "faire face" OR mitigat* OR atténu* OR reduc* OR réduc* OR impact* OR loss* OR perte$ OR damage$ OR dégâts OR respon* OR répon* OR disast* OR catastroph* OR capacit* OR protect* OR warn* OR alert* OR transfer OR transfert OR retention OR rétention OR insur* OR assur* OR reinsur* OR réassur* OR remittance* OR versement* OR aid$ OR help* OR mutu?l* OR gift* OR cadeau* OR shar* OR partag* OR cr?dit* OR fund* OR fonds OR r?serve$ OR saving* OR économi* OR income$ OR revenu$ OR poverty OR poor* OR pauvre* OR livelihood$ OR subsistence OR agricultur* OR bank$ OR banque$ OR government* OR gouvernement* OR famil* OR commun* OR network$ OR réseau$) AND TITLE-ABS-KEY ("west* africa*" OR "afrique de l'ouest" OR "ouest-africain*" OR benin* OR bénin* OR togo* OR senegal* OR sénégal* OR gambia* OR gambie* OR guinea* OR guinée* OR "guinea-bissau*" OR "guinée-bissau*" OR "bissau-guinéen*" OR mali* OR "ivory coast" OR ivorian* OR "côte d'ivoire" OR ivoirien* OR "sierra leone*" OR "sierra léon*" OR "burkina faso" OR burkinab* OR niger* OR nigér* OR nigeria* OR nigéria* OR ghan* OR liberia* OR libérien* OR "cap-ver*" OR "cape verd*") AND PUBYEAR > 1990 AND PUBYEAR < 2020 AND LANGUAGE (english OR french) AND DOCTYPE (ar OR ch) AND NOT TITLE-ABS-KEY (malicious OR malignant OR "Papua New Guinea" OR attack*) -> **1,539 documents**

African Journals Online (AJOL) (earliest date possible in this database is 2004):

(flood* OR *in?nd* OR crue*) AND (*risk* OR risque* OR r?sidu?l* OR management OR gestion OR vuln?rab* OR adapt* OR r?silien* OR cop* OR "faire face" OR mitigat* OR atténu* OR r?duc* OR impact* OR loss* OR perte$ OR damage$ OR dégâts OR r?$pon* OR disast* OR catastroph* OR capacit* OR protect* OR warn* OR alert* OR transfer$ OR r?tention OR insur* OR assur* OR reinsur* OR réassur* OR remittance* OR versement* OR aid$ OR help* OR mutu?l* OR gift* OR cadeau* OR shar* OR partag* OR cr?dit* OR fund* OR fonds OR r?serve$ OR saving* OR économi* OR income$ OR revenu$ OR poverty OR poor* OR pauvre* OR livelihood$ OR subsistence OR agricultur* OR bank$ OR banque$ OR go$vern$ment* OR famil* OR commun* OR network$ OR réseau$)

Search period: 01/01/2004 – 31/12/2019 -> **173 documents**

Annex 2 List of selected documents

[1] Abass, K.; Dumedah, G.; Frempong, F. (2019): Understanding the physical and human contexts of fluvial floods in rural Ghana. In International Journal of River Basin Management, pp. 1–12. DOI: 10.1080/15715124.2019.1653310.

[2] Abu, M.; Codjoe, S. (2018): Experience and future perceived risk of floods and diarrheal disease in urban poor communities in Accra, Ghana. In International Journal of Environmental Research and Public Health 15, p. 2830. DOI: 10.3390/ijerph15122830.

[3] Addo, I. Y.; Danso, S. Y. (2017): Sociocultural factors and perceptions associated with voluntary and permanent relocation of flood victims: A case study of Sekondi-Takoradi Metropolis in Ghana. In Jàmbá: Journal of Disaster Risk Studies 9 (1), p. 303. DOI: 10.4102/jamba.v9i1.303.

[4] Adebo, G.; Ayelari, T. (2011): Climate change and vulnerability of fish farmers in Southwestern Nigeria. In African Journal of Agricultural Research 6.

[5] Adejuwon, G. A.; Aina, W. J. (2014): Emergency preparedness and response to Ibadan flood disaster 2011: Implications for wellbeing. In Mediterranean Journal of Social Sciences, pp. 500–511. DOI: 10.5901/mjss.2014.v5n8p500.

[6] Adekola, O.; Lamond, J.; Adelekan, I.; Eze, E. B. (2019): Evaluating flood adaptation governance in the city of Calabar, Nigeria. In Climate and Development, pp. 1–14. DOI: 10.1080/17565529.2019.1700771.

[7] Adelekan, I. O. (2010): Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. In Environment and Urbanization 22 (2), pp. 433–450. DOI: 10.1177/0956247810380141.

[8] Adelekan, I. O. (2011): Vulnerability assessment of an urban flood in Nigeria: Abeokuta flood 2007. In Natural Hazards 56 (1), pp. 215–231. DOI: 10.1007/s11069-010-9564-z.

[9] Adelekan, I. O. (2016): Flood risk management in the coastal city of Lagos, Nigeria. In Journal of Flood Risk Management 9 (3), pp. 255–264. DOI: 10.1111/jfr3.12179.

[10] Adelekan, I. O.; Asiyanbi, A. P. (2016): Flood risk perception in flood-affected communities in Lagos, Nigeria. In Natural Hazards 80 (1), pp. 445–469. DOI: 10.1007/s11069-015-1977-2.

[11] Adelekan, I. O.; Fregene, T. (2015): Vulnerability of artisanal fishing communities to flood risks in coastal southwest Nigeria. In Climate and Development 7 (4), pp. 322–338. DOI: 10.1080/17565529.2014.951011.

[12] Adeleye, B.; Popoola, A. (2019): Poor development control as flood vulnerability factor in Suleja, Nigeria. In Town and Regional Planning 74 (1), pp. 23–35. DOI: 10.18820/2415-0495/trp74i1.3.

[13] Adeleye, B. M.; Ayangbile, O. A. (2016): Flood vulnerability: Impending danger in Sabon-Gari Minna, Niger State, Nigeria. In Ethiopian Journal of Environmental Studies and Management 9 (1), pp. 35–44. DOI: 10.4314/ejesm.v9i1.4.

[14] Adewole, I. F.; Agbola, S. B.; Kasim, O. F. (2015): Building resilience to climate change impacts after the 2011 flood disaster at the University of Ibadan, Nigeria. In Environment and Urbanization 27 (1), pp. 199–216. DOI: 10.1177/0956247814547679.

[15] Afriyie, K.; Ganle, J. K.; Santos, E. (2018): 'The floods came and we lost everything': weather extremes and households' asset vulnerability and adaptation in rural Ghana. In Climate and Development 10 (3), pp. 259–274. DOI: 10.1080/17565529.2017.1291403.

[16] Agbola, B. S.; Ajayi, O.; Taiwo, O. J.; Wahab, B. W. (2012): The August 2011 flood in Ibadan, Nigeria: Anthropogenic causes and consequences. In International Journal of Disaster Risk Science 3 (4), pp. 207–217. DOI: 10.1007/s13753-012-0021-3.

[17] Ahadzie, D. K.; Dinye, I.; Dinye, R. D.; Proverbs, D. G. (2016): Flood risk perception, coping and management in two vulnerable communities in Kumasi, Ghana. In International Journal of Safety and Security Engineering 6 (3), pp. 538–549. DOI: 10.2495/SAFE-V6-N3-538-549.

[18] Ahmed, S. D.; Agodzo, S. K.; Adjei, K. A.; Deinmodei, M.; Ameso, V. C. (2018): Preliminary investigation of flooding problems and the occurrence of kidney disease around Hadejia-Nguru

wetlands, Nigeria and the need for an ecohydrology solution. In Ecohydrology & Hydrobiology 18 (2), pp. 212–224. DOI: 10.1016/j.ecohyd.2017.11.005.

[19] Ajaero, C. K. (2017): A gender perspective on the impact of flood on the food security of households in rural communities of Anambra state, Nigeria. In Food Security 9 (4), pp. 685–695. DOI: 10.1007/s12571-017-0695-x.

[20] Ajaero, C. K.; Mozie, A.; Abu, I. (2018): Migrating from migratory waters to migration of livelihoods. In Social Indicators Research 136, pp. 1–15. DOI: 10.1007/s11205-016-1524-x.

[21] Ajaero, I. D.; Okoro, N. M.; Ajaero, C. K. (2016): Perception of and attitude toward mass media reportage of the 2012 flood in rural Nigeria. In SAGE Open 6 (3), 215824401666688. DOI: 10.1177/2158244016666887.

[22] Ajaero C.K., Mozie A.T., Anaelo C.N. (2018): Gender mainstreaming of the impacts of 2012 flood-induced migration on household livelihoods in Nigeria. In International Journal of Sustainable Development 21 (1/2/3/4), pp. 18–35.

[23] Ajibade, E. T.; Babatunde, R. O.; Ajibade, T. B.; Akinsola, G. O. (2019): Empirical analysis of adaptation strategies used in mitigating flood related losses by rice farmers in Kwara State, Nigeria. In Agrosearch 19 (1), pp. 59–71. DOI: 10.4314/agrosh.v19i1.5.

[24] Ajibade, I.; Armah, F.; Kuuire, V.; Luginaah, I.; McBean, G. (2015a): Self-reported experiences of climate change in Nigeria: The role of personal and socio-environmental factors. In Climate 3 (1), pp. 16–41. DOI: 10.3390/cli3010016.

[25] Ajibade, I.; Armah, F.; Kuuire, V.; Luginaah, I.; McBean, G.; Tenkorang, E. (2015b): Assessing the bio-psychosocial correlates of flood impacts in coastal areas of Lagos, Nigeria. In Journal of Environmental Planning and Management 58 (3), pp. 445–463. DOI: 10.1080/09640568.2013.861811#.Ut_3wBD8W01.

[26] Ajibade, I.; McBean, G. (2014): Climate extremes and housing rights: A political ecology of impacts, early warning and adaptation constraints in Lagos slum communities. In Geoforum 55, pp. 76–86. DOI: 10.1016/j.geoforum.2014.05.005.

[27] Ajibade, I.; McBean, G.; Bezner-Kerr, R. (2013): Urban flooding in Lagos, Nigeria: Patterns of vulnerability and resilience among women. In Global Environmental Change 23 (6), pp. 1714–1725. DOI: 10.1016/j.gloenvcha.2013.08.009.

[28] Ajibade, I.; Olawuyi, D. S. (2017): Climate change impacts on housing and property rights in Nigeria and Panama: Toward a rights-based approach to adaptation and mitigation. In D. Stucker, E Lopez-Gunn (Eds.): Adaptation to climate change through water resources management. Capacity, Equity and Sustainability: Routledge, pp. 264–284.

[29] Akukwe, T. I.; Ogbodo, C. (2015): Spatial analysis of vulnerability to flooding in Port Harcourt metropolis, Nigeria. In SAGE Open 5 (1), 2158244015575558. DOI: 10.1177/2158244015575558.

[30] Alou, A. A.; Lutoff, C.; Mounkaila, H. (2019): Relocalisation préventive suite à la crue de Niamey 2012 : vulnérabilités socio-économiques émergentes et retour en zone inondable. In Cybergeo: European Journal of Geography, Regional and Urban Planning. DOI: 10.4000/cybergeo.32601.

[31] Amoako, C. (2016): Brutal presence or convenient absence: The role of the state in the politics of flooding in informal Accra, Ghana. In Geoforum 77, pp. 5–16. DOI: 10.1016/j.geoforum.2016.10.003.

[32] Amoako, C. (2018): Emerging grassroots resilience and flood responses in informal settlements in Accra, Ghana. In GeoJournal 83 (5), pp. 949–965. DOI: 10.1007/s10708-017-9807-6.

[33] Amoako, C.; Cobbinah, P. B.; Mensah Darkwah, R. (2019): Complex twist of fate: The geopolitics of flood management regimes in Accra, Ghana. In Cities 89, pp. 209–217. DOI: 10.1016/j.cities.2019.02.006.

[34] Amoako, C.; Inkoom, D. K. B. (2017): The production of flood vulnerability in Accra, Ghana: Re-thinking flooding and informal urbanisation. In Urban Studies 55 (13), pp. 2903–2922. DOI: 10.1177/0042098016686526.

[35] Amusat, A. S.; Amusat, K. K. (2013): Effects of flood on farmers in peri-urban area of Ibadan, Oyo State, Nigeria. In Journal of Environmental Extension 11, pp. 27–31.

[36] Amuzu, J.; Jallow, B.; Kabo-Bah, A.; Yaffa, S. (2018): The climate change vulnerability and risk management matrix for the coastal zone of The Gambia. In Hydrology 5 (1), p. 14. DOI: 10.3390/hydrology5010014.

[37] Antwi, E. K.; Boakye-Danquah, J.; Barima Owusu, A.; Loh, S. K.; Mensah, R.; Boafo, Y. A.; Apronti, P. T. (2015): Community vulnerability assessment index for flood prone savannah agro-ecological zone: A case study of Wa West District, Ghana. In Weather and Climate Extremes 10, pp. 56–69. DOI: 10.1016/j.wace.2015.10.008.

[38] Antwi-Boasiako, B. A. (2016): Insurance and flood risk reduction in Ghana: do insurers penalise homeowners who take precautionary measures? In Environmental Hazards 15 (4), pp. 343–355. DOI: 10.1080/17477891.2016.1209455.

[39] Antwi-Boasiako, B. A. (2017): It's beyond my control: The effect of locus of control orientation on disaster insurance adoption. In International Journal of Disaster Risk Reduction 22, pp. 297–303. DOI: 10.1016/j.ijdrr.2017.02.014.

[40] Atidegla, S. C.; Koumassi, H. D.; Houssou, E. S. (2017): Variabilité climatique et production maraîchère dans la plaine inondable d'Ahomey-Gblon au Bénin. In International Journal of Biological and Chemical Sciences 11 (5), pp. 2254–2269. DOI: 10.4314/ijbcs.v11i5.24.

[41] Biconne, R. (2014): Knowledge sharing on climate change as a resource for adaptation processes: The case of Malika, Senegal. In S. Macchi, M. Tiepolo (Eds.): Climate change vulnerability in southern African cities: Building knowledge for adaptation. Cham: Springer International Publishing, pp. 125–140. Available online at https://doi.org/10.1007/978-3-319-00672-7_8.

[42] Boamah, S.; Armah, F.; Kuuire, V.; Ajibade, I.; Luginaah, I.; McBean, G. (2015): Does previous experience of floods stimulate the adoption of coping strategies? Evidence from cross sectional surveys in Nigeria and Tanzania. In Environments 2 (4), pp. 565–585. DOI: 10.3390/environments2040565.

[43] Bonye, S.; Jasaw, G. (2011): Traditional coping mechanism in disaster management in the Builsa and Sissala districts of northern Ghana. In European Journal of Social Sciences 25, pp. 204–218.

[44] Bottazzi, P.; Winkler, M.; Boillat, S.; Diagne, A.; Maman Chabi, Sika, M.; Kpangon, A. et al. (2018): Measuring subjective flood resilience in suburban Dakar: A before–after evaluation of the "Live with Water" project. In Sustainability 10 (7), p. 2135. DOI: 10.3390/su10072135.

[45] Bottazzi, P.; Winkler, M. S.; Ifejika Speranza, C. (2019): Flood governance for resilience in cities: The historical policy transformations in Dakar's suburbs. In Environmental Science & Policy 93, pp. 172–180. DOI: 10.1016/j.envsci.2018.12.013.

[46] Boubacar, S.; Pelling, M.; Barcena, A.; Montandon, R. (2017): The erosive effects of small disasters on household absorptive capacity in Niamey: a nested HEA approach. In Environment and Urbanization 29 (1), pp. 33–50. DOI: 10.1177/0956247816685515.

[47] Brisibe, W. G.; Pepple, T. D. (2018): Lessons learnt from the 2012 flood disaster: Implications for post-flood building design and construction in Yenagoa, Nigeria. In Civil Engineering and Architecture 6 (3), pp. 171–180. DOI: 10.13189/cea.2018.060307.

[48] Campion, B. B.; Venzke, J.-F. (2013): Rainfall variability, floods and adaptations of the urban poor to flooding in Kumasi, Ghana. In Natural Hazards 65 (3), pp. 1895–1911. DOI: 10.1007/s11069-012-0452-6.

[49] Chukwu, M. N. (2015): Impact of flooding on fishermen's families in Pedro community, Iwaya-Lagos, Nigeria. In Journal of Applied Sciences and Environmental Management 18 (4), pp. 647–651. DOI: 10.4314/jasem.v18i4.13.

[50] Chukwuma, O. M.; Uchenna, O. F. (2018): A comparative analysis of flooding in Warri and Port Harcourt urban areas of the Niger Delta region in southern Nigeria. In Arabian Journal of Geosciences 11 (8), p. 166. DOI: 10.1007/s12517-018-3525-3.

[51] Cirella, G.; Iyalomhe, F.; Adekola, O. (2019): Determinants of flooding and strategies for mitigation: Two-year case study of Benin City. In Geosciences (Switzerland) 9. DOI: 10.3390/geosciences9030136.

[52] Cissé, O.; Sèye, M. (2016): Flooding in the suburbs of Dakar: impacts on the assets and adaptation strategies of households or communities. In Environment and Urbanization 28 (1), pp. 183–204. DOI: 10.1177/0956247815613693.

[53] Clark-Ginsberg, A. (2017): Participatory risk network analysis: A tool for disaster reduction practitioners. In International Journal of Disaster Risk Reduction 21, pp. 430–437. DOI: 10.1016/j.ijdrr.2017.01.006.

[54] Codjoe, S. N. A.; Atidoh, L. K.; Burkett, V. (2012): Gender and occupational perspectives on adaptation to climate extremes in the Afram Plains of Ghana. In Climatic Change 110 (1), pp. 431–454. DOI: 10.1007/s10584-011-0237-z.

[55] Codjoe, S. N. A.; Issah, A. D. (2016): Cultural dimension and adaptation to floods in a coastal settlement and a savannah community in Ghana. In GeoJournal 81 (4), pp. 615–624. DOI: 10.1007/s10708-015-9641-7.

[56] Codjoe, S. N. A.; Nyamedor, F. H.; Sward, J.; Dovie, D. B. (2017): Environmental hazard and migration intentions in a coastal area in Ghana: a case of sea flooding. In Population and Environment 39 (2), pp. 128–146. DOI: 10.1007/s11111-017-0284-0.

[57] Codjoe, S. N. A.; Owusu, G.; Burkett, V. (2014): Perception, experience, and indigenous knowledge of climate change and variability: the case of Accra, a sub-saharan African city. In Regional Environmental Change 14 (1), pp. 369–383. DOI: 10.1007/s10113-013-0500-0.

[58] Coker, A. A.; Adebayo, C. O.; Odoemena, B. C.; Akogun, E. O.; Ezinne, C. G. (2014): Flood and cassave productivity in Kogi State, Nigeria: A quantitative analysis using cross-sectional data. In

Ethiopian Journal of Environmental Studies and Management 7 (6), pp. 599–608. DOI: 10.4314/ejesm.v7i6.2.

[59] Danso, S. Y.; Addo, I. Y. (2017): Coping strategies of households affected by flooding: A case study of Sekondi-Takoradi Metropolis in Ghana. In Urban Water Journal 14 (5), pp. 539–545. DOI: 10.1080/1573062X.2016.1176223.

[60] Derbile, E.; File, D.; Dongzagla, A. (2016): The double tragedy of agriculture vulnerability to climate variability in Africa: How vulnerable is smallholder agriculture to rainfall variability in Ghana? In Jàmbá: Journal of Disaster Risk Studies 8. DOI: 10.4102/jamba.v8i3.249.

[61] Diagne, K. (2007): Governance and natural disasters: addressing flooding in Saint Louis, Senegal. In Environment and Urbanization 19 (2), pp. 552–562. DOI: 10.1177/0956247807082836.

[62] Diagne, K.; Ndiaye, A. (2012): History, governance and the millennium development goals: Flood risk reduction in Saint-Louis, Senegal. In M. Pelling, B. Wisner (Eds.): Disaster risk reduction. Cases from Urban Africa: Routledge, pp. 147–167.

[63] Egbinola, C. N.; Olaniran, H. D.; Amanambu, A. C. (2017): Flood management in cities of developing countries: the example of Ibadan, Nigeria. In Journal of Flood Risk Management 10 (4), pp. 546–554. DOI: 10.1111/jfr3.12157.

[64] Ekpo, F.; Nzegblue, E. C. (2012): Climate change impact and adaptation opportunities on agricultural production in communities around Itu bridge-head in Itu LGA, Akwa Ibom State, Nigeria. In Agris On-line Papers in Economics and Informatics 2, pp. 2239–2250. DOI: 10.6088/ijes.002020300107.

[65] Enete, A.; Nneamaka, O.; Ozor, N.; Lilian, M. (2016): Socioeconomic assessment of flooding among farm households in Anambra state, Nigeria. In International Journal of Climate Change Strategies and Management 8, pp. 96–111. DOI: 10.1108/IJCCSM-07-2014-0084.

[66] Evadzi, P. I. K.; Scheffran, J.; Zorita, E.; Hünicke, B. (2018): Awareness of sea-level response under climate change on the coast of Ghana. In Journal of Coastal Conservation 22 (1), pp. 183–197. DOI: 10.1007/s11852-017-0569-6.

[67] Ezemonye, M. N.; Emeribe, C. N. (2014): Flooding and household preparedness in Benin City, Nigeria. In Mediterranean Journal of Social Sciences. DOI: 10.5901/mjss.2014.v5n1p547.

[68] Frick-Trzebitzky, F. (2017): Crafting adaptive capacity: Institutional bricolage in adaptation to urban flooding in Greater Accra. In Water Alternatives 10 (2), pp. 625–647.

[69] Frick-Trzebitzky, F.; Bruns, A. (2019): Disparities in the implementation gap: adaptation to flood risk in the Densu Delta, Accra, Ghana. In Journal of Environmental Policy & Planning 21 (5), pp. 577–592. DOI: 10.1080/1523908X.2017.1343136.

[70] Glago, F. J. (2019): Household disaster awareness and preparedness: A case study of flood hazards in Asamankese in the West Akim Municipality of Ghana. In Jàmbá: Journal of Disaster Risk Studies 11 (1), p. 789. DOI: 10.4102/jamba.v11i1.789.

[71] Gobo A.E.; Abam T.K.S. (1991): The 1988 floods in the Niger Delta: The Case of Ndoni. In Journal of Meteorology 16 (163), pp. 293–299.

[72] Gobo A.E.; Abam T.K.S.; Ogam F.N. (2006): The application of Kruskal-Wallis technique for flood prediction in the Niger Delta, Nigeria. In Management of Environmental Quality: An International Journal 17 (3), pp. 275–288. DOI: 10.1108/14777830610658692.

[73] Goyol, S.; Pathirage, C. (2018): Farmers perceptions of climate change related events in Shendam and Riyom, Nigeria. In Economies 6, p. 70. DOI: 10.3390/economies6040070.

[74] Hetcheli, F. (2013): Risques pluviometriques et nouvelles orientations des agriculteurs du canton de Togblekope (Basse Vallee de Zio) au Togo. In Journal de la Recherche Scientifique de l'Université de Lomé - Série B 15 (2), pp. 135–149.

[75] Ibitoye, M. O.; Komolafe, A. A.; Adegboyega, A. S.; Adebola, A. O.; Oladeji, O. D. (2019): Analysis of vulnerable urban properties within river Ala floodplain in Akure, Southwestern Nigeria. In Spatial Information Research. DOI: 10.1007/s41324-019-00298-6.

[76] Ibrahim, A. H.; Abdullahi, S. Z. (2016): Flood menace in Kaduna metropolis: Impacts, remedial and management strategies. In Science World Journal 11 (2), 16-22.

[77] Ingram, K.T; Roncoli, M.C; Kirshen, P.H (2002): Opportunities and constraints for farmers of West Africa to use seasonal precipitation forecasts with Burkina Faso as a case study. In Agricultural Systems 74 (3), pp. 331–349. DOI: 10.1016/S0308-521X(02)00044-6.

[78] Jallow, B. P.; Toure, S.; Barrow, M. M. K.; Mathieu, A. A. (1999): Coastal zone of The Gambia and the Abidjan region in Côte d'Ivoire. Sea level rise vulnerability, response strategies, and adaptation options. In Climate Research 12 (2/3), pp. 129–136.

[79] Kablan, M.; Dongo, K.; Coulibaly, M. (2017): Assessment of social vulnerability to flood in urban Côte d'Ivoire using the MOVE framework. In Water 9, p. 292. DOI: 10.3390/w9040292.

[80] Kablan, M.; Dongo, K.; Fokou, G.; Coulibaly, M. (2019): Assessing population perception and socioeconomic impact related to flood episodes in urban Côte d'Ivoire. In International Journal of Biological and Chemical Sciences 13 (4), pp. 2210–2223. DOI: 10.4314/ijbcs.v13i4.26.

[81] Kielland, A. (2016): The role of risk perception in child mobility decisions in West Africa, empirical evidence from Benin. In World Development 83, pp. 312–324. DOI: 10.1016/j.worlddev.2016.01.008.

[82] Kloos, J.; Renaud, F. (2014): Organic cotton production as an adaptation option in north-west Benin. In Outlook on Agriculture 43, pp. 91–100. DOI: 10.5367/oa.2014.0166.

[83] Komi, K.; Amisigo, B.; Diekkrüger, B. (2016): Integrated flood risk assessment of rural communities in the Oti River basin, West Africa. In Hydrology 3 (4), p. 42. DOI: 10.3390/hydrology3040042.

[84] Lamond, J.; Adekola, O.; Adelekan, I.; Eze, E.; Ujoh, F. (2019): Information for adaptation and response to flooding, multi-stakeholder perspectives in Nigeria. In Climate 7, pp. 1–18. DOI: 10.3390/cli7040046.

[85] Leclercq, R. (2017): The politics of risk policies in Dakar, Senegal. In International Journal of Disaster Risk Reduction 26, pp. 93–100. DOI: 10.1016/j.ijdrr.2017.09.031.

[86] Lokonon, B. O. K. (2016): Urban households' attitude towards flood risk, and waste disposal: Evidence from Cotonou. In International Journal of Disaster Risk Reduction 19, pp. 29–35. DOI: 10.1016/j.ijdrr.2016.08.015.

[87] Lolig, V.; Donkoh, S.; Obeng, F. K.; Gershon, I.; Ansah, I.; Jasaw, G. et al. (2014): Households' coping strategies in drought-and flood-prone communities in Northern Ghana. In Journal of Disaster Research 9, pp. 542–553.

[88] Maheu, A. (2012): Urbanization and flood vulnerability in a peri-urban neighbourhood of Dakar, Senegal: How can participatory GIS contribute to flood management? In W. Leal Filho (Ed.): Climate change and the sustainable use of water resources. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 185–207. Available online at https://doi.org/10.1007/978-3-642-22266-5_12.

[89] Markantonis, V.; Farinosi, F.; Dondeynaz, C.; Ameztoy, I.; Pastori, M.; Marletta, L. et al. (2018): Assessing floods and droughts in the Mékrou River basin (West Africa): A combined household survey and climatic trends analysis approach. In Natural Hazards and Earth System Sciences 18 (4), pp. 1279–1296. DOI: 10.5194/nhess-18-1279-2018.

[90] Martins, B.; Nunes, A.; Lourenço, L.; Velez-Castro, F. (2019): Flash Flood Risk Perception by the Population of Mindelo, S. Vicente (Cape Verde). In Water 11 (9). DOI: 10.3390/w11091895.

[91] Mbow, C.; Diop, A.; Diaw, A. T.; Niang, C. I. (2008): Urban sprawl development and flooding at Yeumbeul suburb (Dakar-Senegal). In African Journal of Environmental Science and Technology 2 (4), pp. 75–88.

[92] Milliano, C.W.J. de (2015): Luctor et emergo, exploring contextual variance in factors that enable adolescent resilience to flooding. In International Journal of Disaster Risk Reduction 14, pp. 168–178. DOI: 10.1016/j.ijdrr.2015.07.005.

[93] Morand, P.; Kodio, A.; Andrew, N.; Sinaba, F.; Lemoalle, J.; Béné, C. (2012): Vulnerability and adaptation of African rural populations to hydro-climate change: experience from fishing communities in the Inner Niger Delta (Mali). In Climatic Change 115 (3), pp. 463–483. DOI: 10.1007/s10584-012-0492-7.

[94] Ndamani, F.; Watanabe, T. (2016): Determinants of farmers' adaptation to climate change: A micro level analysis in Ghana. In Scientia Agricola 73, pp. 201–208. DOI: 10.1590/0103-9016-2015-0163.

[95] Ngwese, N. M.; Saito, O.; Sato, A.; Agyeman Boafo, Y.; Jasaw, G. (2018): Traditional and local knowledge practices for disaster risk reduction in Northern Ghana. In Sustainability 10 (3), p. 825. DOI: 10.3390/su10030825.

[96] Ntajal, J.; Lamptey, B. L.; Mahamadou, I. B.; Nyarko, B. K. (2017): Flood disaster risk mapping in the Lower Mono River Basin in Togo, West Africa. In International Journal of Disaster Risk Reduction 23, pp. 93–103. DOI: 10.1016/j.ijdrr.2017.03.015.

[97] Nti, Frank; Barkley, Andrew (2013): The impact of human capital on the response to climate change vulnerability among farm families in Northern Ghana. In Journal of International Agricultural Trade and Development 8.

[98] Nyantakyi-Frimpong, H. (2019): Unmasking difference: intersectionality and smallholder farmers' vulnerability to climate extremes in Northern Ghana. In Gender, Place & Culture, pp. 1–19. DOI: 10.1080/0966369X.2019.1693344.

[99] Odemerho, F. O. (2014): Building climate change resilience through bottom-up adaptation to flood risk in Warri, Nigeria. In Environment and Urbanization 27 (1), pp. 139–160. DOI: 10.1177/0956247814558194.

[100] Odjugo, P. A. O. (2012): Valuing the cost of environmental degradation in the face of changing climate: Emphasis on flood and erosion in Benin City, Nigeria. In African Journal of Environmental Science and Technology 6 (1), pp. 17–27. DOI: 10.5897/AJEST11.174.

[101] Odubo, T. (2014): The socio-cultural effects of flooding in Bayelsa State: A case study of Southern Ijaw Local Government Area. In Mediterranean Journal of Social Sciences 5, pp. 1443–1450. DOI: 10.5901/mjss.2014.v5n27p1443.

[102] Olanrewaju, C. C.; Chitakira, M.; Olanrewaju, O. A.; Louw, E. (2019): Impacts of flood disasters in Nigeria: A critical evaluation of health implications and management. In Jàmbá: Journal of Disaster Risk Studies 11 (1), p. 557. DOI: 10.4102/jamba.v11i1.557.

[103] Ologunorisa, T. E.; Adeyemo, A. (2005): Public perception of flood hazard in the Niger Delta, Nigeria. In Environmentalist 25 (1), pp. 39–45. DOI: 10.1007/s10669-005-3095-2.

[104] Olokesusi, F.; Olorunfemi, F. B.; Onwuemele, A.; Oke, M. O. (2015): Awareness of and responses to the 2011 flood warnings among vulnerable communities in Lagos, Nigeria. In B. Werlen (Ed.): Global sustainability, vol. 27. Cham: Springer International Publishing, pp. 203–223.

[105] Onu, B.; Price, T.; Surendran, S.; Timbiri, A. (2013): Peoples' perception on the effects of floods in the riverine areas of Ogbia Local Government Area of Bayelsa State, Nigeria. In Knowledge Management: An International Journal 12, pp. 22–43. DOI: 10.18848/2327-7998/CGP/v12i02/50793.

[106] Onwuemele, A. (2012): Cities in the flood: Vulnerability and disaster risk management: Evidence from Ibadan, Nigeria. In W. G. Holt (Ed.): Urban areas and global climate change, vol. 12: Emerald Group Publishing Limited (Research in Urban Sociology), pp. 277–299.

[107] Onwuemele, A. (2018): Public perception of flood risks and disaster preparedness in Lagos megacity, Nigeria. In Academic Journal of Interdisciplinary Studies 7 (3), pp. 179–185. DOI: 10.2478/ajis-2018-0068.

[108] Osayomi, T.; Oladosu, O. S. (2016): "Expect more floods in 2013": An analysis of flood preparedness in the flood prone city of Ibadan, Nigeria. In African Journal of Sustainable Development 6 (2), pp. 215–237.

[109] Osman, A.; Nyarko, B. K.; Mariwah, S. (2016): Vulnerability and risk levels of communities within Ankobra estuary of Ghana. In International Journal of Disaster Risk Reduction 19, pp. 133–144. DOI: 10.1016/j.ijdrr.2016.08.016.

[110] Ottah, G. A. (2017): Impact of Radio Kogi's flood disaster awareness campaign on residents of Ibaji Local Government Area of Kogi State, Nigeria. In International Journal of Arts and Humanities (IJAH) Ethiopia 6 (3), pp. 80–97. DOI: 10.4314/ijah.v6i3.7.

[111] Owusu-Ansah, J. K.; Dery, J. M.; Amoako, C. (2019): Flood vulnerability and coping mechanisms around the Weija Dam near Accra, Ghana. In GeoJournal 84 (6), pp. 1597–1615. DOI: 10.1007/s10708-018-9939-3.

[112] Oyekale, A. S. (2013): Fishing folks' access to early warning and post flood assistances in Lagos State, Nigeria: Application of seemingly unrelated bivariate probit (SUBP) regression. In Journal of Animal and Veterinary Advances 12, pp. 607–611. DOI: 10.3923/javaa.2013.607.611.

[113] Oyekale, A. S.; Oladele, O. I.; Mukela, F. (2013): Impacts of flooding on coastal fishing folks and risk adaptation behaviours in Epe, Lagos State. In African Journal of Agricultural Research 8 (26), pp. 3392–3405. DOI: 10.5897/AJAR12.730.

[114] Oyerinde, G. T.; Lawin, E. A.; Odofin, A. J. (2017): Farmers' responses to changing hydrological trends in the Niger Basin parts of Benin. In Hydrology 4 (4), p. 52. DOI: 10.3390/hydrology4040052.

[115] Redshaw, P.; Boon, D.; Campbell, G.; Willis, M.; Mattai, J.; Free, M. et al. (2019): The 2017 Regent Landslide, Freetown Peninsula, Sierra Leone. In Quarterly Journal of Engineering Geology and Hydrogeology 52 (4), pp. 435–444. DOI: 10.1144/qjegh2018-187.

[116] Sabino, A. A.; Querido, A. L.; Sousa, M. I. (1999): Flood management in Cape Verde. The case study of Praia. In Urban Water 1 (2), pp. 161–166. DOI: 10.1016/S1462-0758(00)00011-X.

[117] Saidu, I. (2009): An analysis of Loko flood disaster resettlement scheme, in Song Local Government Area of Adamawa State, Nigeria. In FUTY Journal of the Environment 4 (1), pp. 19–27.

[118] Salami, R.; Meding, J. v.; Giggins, H. (2017): Vulnerability of human settlements to flood risk in the core area of Ibadan metropolis, Nigeria. In Jàmbá: Journal of Disaster Risk Studies 9, a371. DOI: 10.4102/jamba.v9i1.371.

[119] Samaddar, S.; Yokomatsu, M.; Dzivenu, T.; Oteng-Ababio, M.; Adams, M. R.; Dayour, F.; Ishikawa, H. (2014): Assessing rural communities concerns for improved climate change adaptation strategies in Northern Ghana. In Journal of Disaster Research 9 (4), pp. 529–541. DOI: 10.20965/jdr.2014.p0529.

[120] Schaer, C. (2015): Condemned to live with one's feet in water? In International Journal of Climate Change Strategies and Management 7 (4), pp. 534–551. DOI: 10.1108/IJCCSM-03-2014-0038.

[121] Schaer, C.; Hanonou, E. K. (2017): The real governance of disaster risk management in peri-urban Senegal: Delivering flood response services through co-production. In Progress in Development Studies 17 (1), pp. 38–53. DOI: 10.1177/1464993416674301.

[122] Schaer, C.; Thiam, M. D.; Nygaard, I. (2018): Flood management in urban Senegal: an actor-oriented perspective on national and transnational adaptation interventions. In Climate and Development 10 (3), pp. 243–258. DOI: 10.1080/17565529.2017.1291405.

[123] Schlef, K.; Kaboré, L.; Karambiri, H.; Yang, Y.-C.; Brown, C. (2018): Relating perceptions of flood risk and coping ability to mitigation behavior in West Africa: Case study of Burkina Faso. In Environmental Science & Policy 89, pp. 254–265. DOI: 10.1016/j.envsci.2018.07.013.

[124] Schultz, K.; Adler, L. (2017): Addressing climate change impacts in the Sahel using vulnerability reduction credits. In M. Tiepolo, A. Pezzoli, V. Tarchiani (Eds.): Renewing local planning to face climate change in the tropics. Cham: Springer International Publishing, pp. 343–363.

[125] Serpantié, G.; Dorée, A.; Fusillier, J.-L.; Moity-Maizi, P.; Lidon, B.; Douanio, M. et al. (2019): Nouveaux risques dans les bas-fonds des terroirs soudaniens. Une étude de cas au Burkina Faso. In Cahiers Agricultures 28, pp. 1–10. DOI: 10.1051/cagri/2019020.

[126] Soneye, A. (2014): An overview of humanitarian relief supply chains for victims of perennial flood disasters in Lagos, Nigeria (2010-2012). In Journal of Humanitarian Logistics and Supply Chain Management 4 (2), pp. 179–197. DOI: 10.1108/JHLSCM-01-2014-0004.

[127] Sousa, J.; Luz, A. L. (2018): 'The tides rhyme with the Moon': The impacts of knowledge transmission and strong spring tides on rice farming in Guinea-Bissau. In Human Ecology 46 (2), pp. 147–157. DOI: 10.1007/s10745-018-9980-3.

[128] Spaling, H. (2003): Innovation in environmental assessment of community-based projects in sub-Saharan Africa. In The Canadian Geographer/Le Géographe canadien 47 (2), pp. 151–168. DOI: 10.1111/1541-0064.00007.

[129] Tasantab, J. C. (2019): Beyond the plan: How land use control practices influence flood risk in Sekondi-Takoradi. In Jàmbá: Journal of Disaster Risk Studies 11 (1), p. 638. DOI: 10.4102/jamba.v11i1.638.

[130] Tiepolo, M.; Rosso, M.; Massazza, G.; Belcore, E.; Issa, S.; Braccio, S. (2019): Flood assessment for risk-informed planning along the Sirba River, Niger. In Sustainability 11, pp. 1–18. DOI: 10.3390/su11154003.

[131] Tschakert, P.; Sagoe, R.; Ofori-Darko, G.; Codjoe, S. N. A. (2010): Floods in the Sahel: an analysis of anomalies, memory, and anticipatory learning. In Climatic Change 103 (3), pp. 471–502. DOI: 10.1007/s10584-009-9776-y.

[132] Twum, K. O.; Abubakari, M. (2019): Cities and floods: A pragmatic insight into the determinants of households' coping strategies to floods in informal Accra, Ghana. In Jàmbá: Journal of Disaster Risk Studies 11 (1), p. 608. DOI: 10.4102/jamba.v11i1.608.

[133] Vedeld, T.; Coly, A.; Ndour, N. M.; Hellevik, S. (2016): Climate adaptation at what scale? Multi-level governance, resilience, and coproduction in Saint Louis, Senegal. In Natural Hazards 82 (2), pp. 173–199. DOI: 10.1007/s11069-015-1875-7.

[134] Vissin, E. W.; Hedible, S.; Amoussou, E.; Totin, H. S.; Odoulami, L.; Etene, C. et al. (2016): Variabilité climatique et hydrologique dans la basse vallée de l'Ouémé à Bonou. In Journal de la Recherche Scientifique de l'Université de Lomé - Série B 18 (2), pp. 69–81.

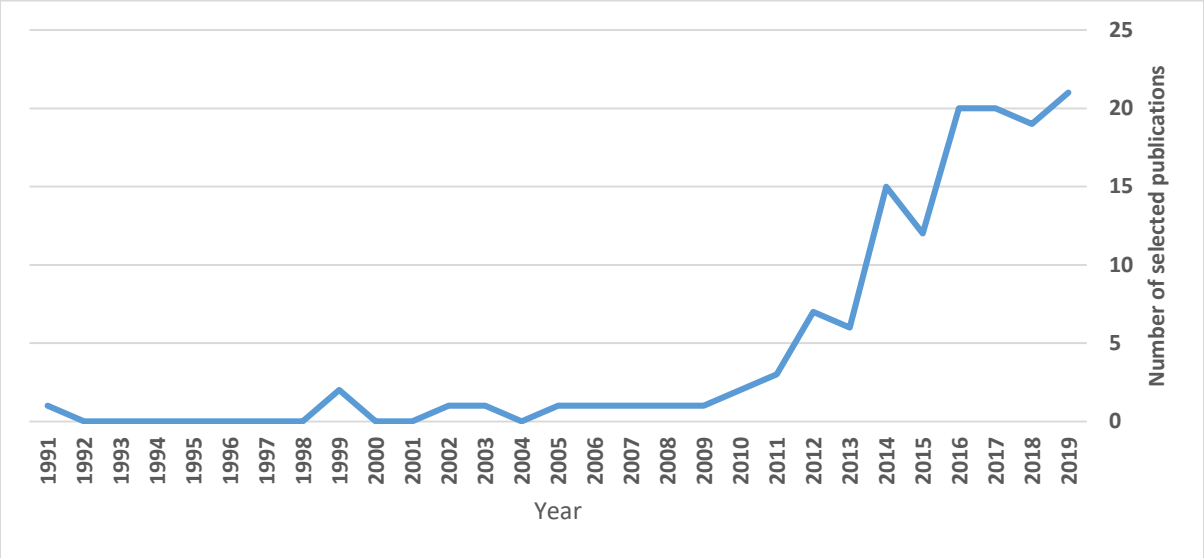
[135] Wahab, B.; Falola, O. (2017): The consequences and policy implications of urban encroachment into flood-risk areas: the case of Ibadan. In Environmental Hazards 16 (1), pp. 1–20. DOI: 10.1080/17477891.2016.1211505.

[136] Yankson, P. W. K.; Owusu, A. B.; Owusu, G.; Boakye-Danquah, J.; Tetteh, J. D. (2017): Assessment of coastal communities' vulnerability to floods using indicator-based approach: a case study of Greater Accra Metropolitan Area, Ghana. In Natural Hazards 89 (2), pp. 661–689. DOI: 10.1007/s11069-017-2985-1.

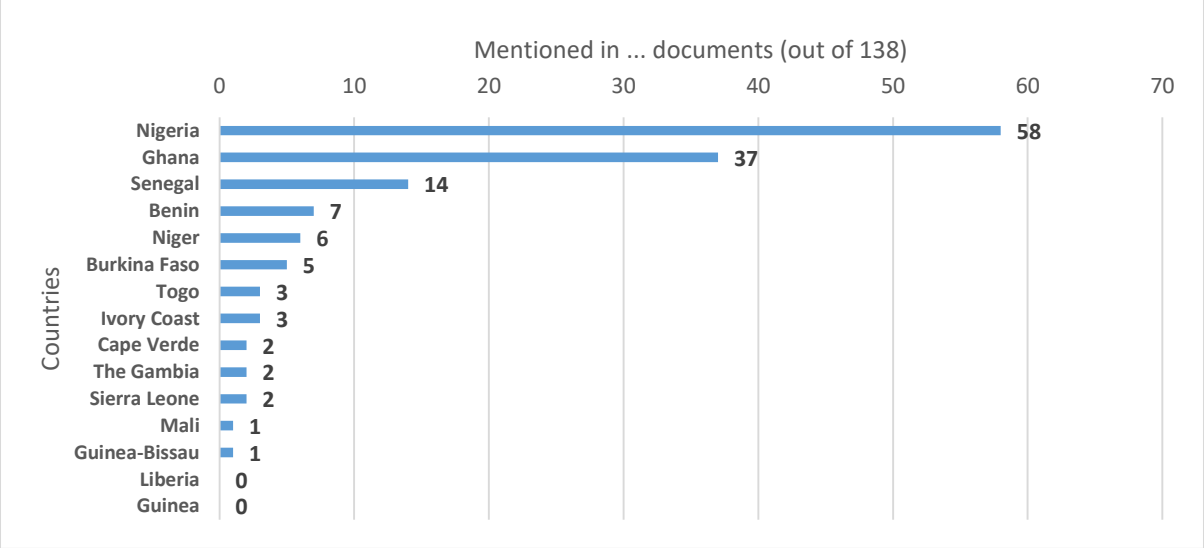
[137] Yawson, D. O.; Adu, M. O.; Armah, F. A.; Kusi, J.; Ansah, I. G.; Chiroro, C. (2015): A needs-based approach for exploring vulnerability and response to disaster risk in rural communities in low income countries. In Australasian Journal of Disaster and Trauma Studies 19, pp. 27–36.

[138] Young, H. R.; Cornforth, R. J.; Gaye, A. T.; Boyd, E. (2019): Event attribution science in adaptation decision-making: the context of extreme rainfall in urban Senegal. In Climate and Development 11 (9), pp. 812–824. DOI: 10.1080/17565529.2019.1571401.

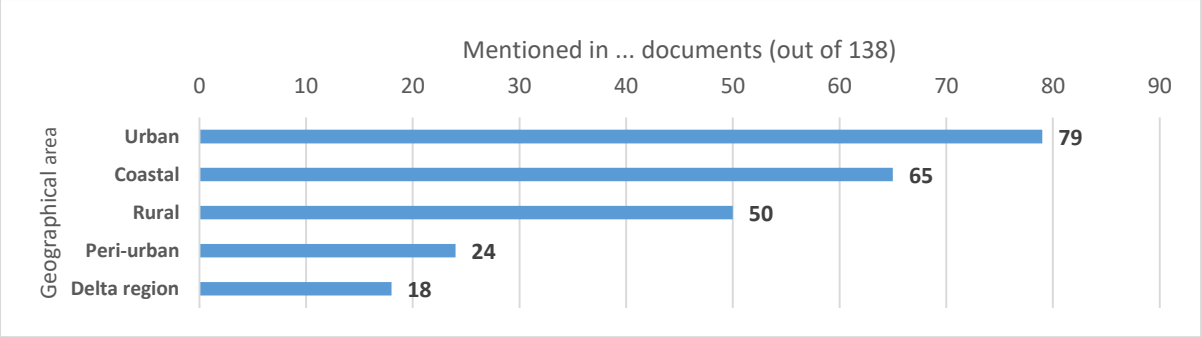
Annex 3 Number of selected documents by year of publication (from 1991 to 2019)



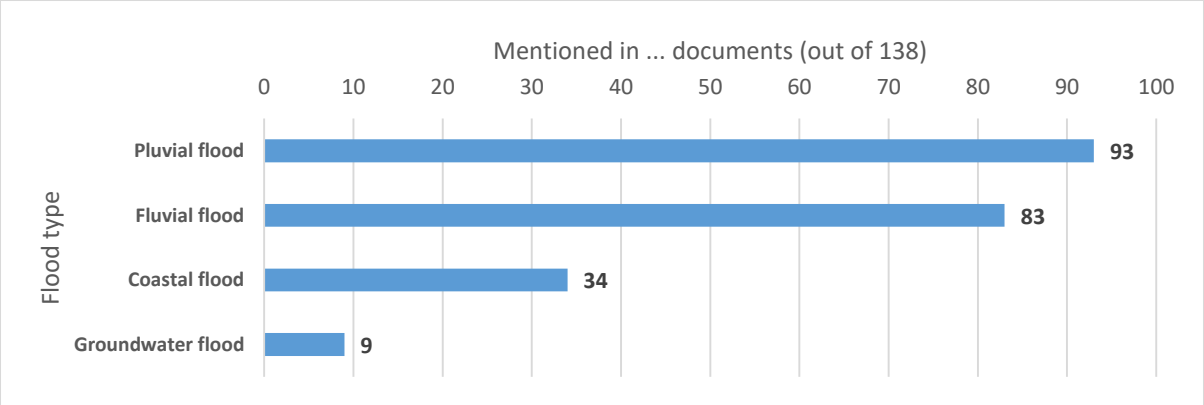
Annex 4 Research areas by country (multiple mentions possible in each document)



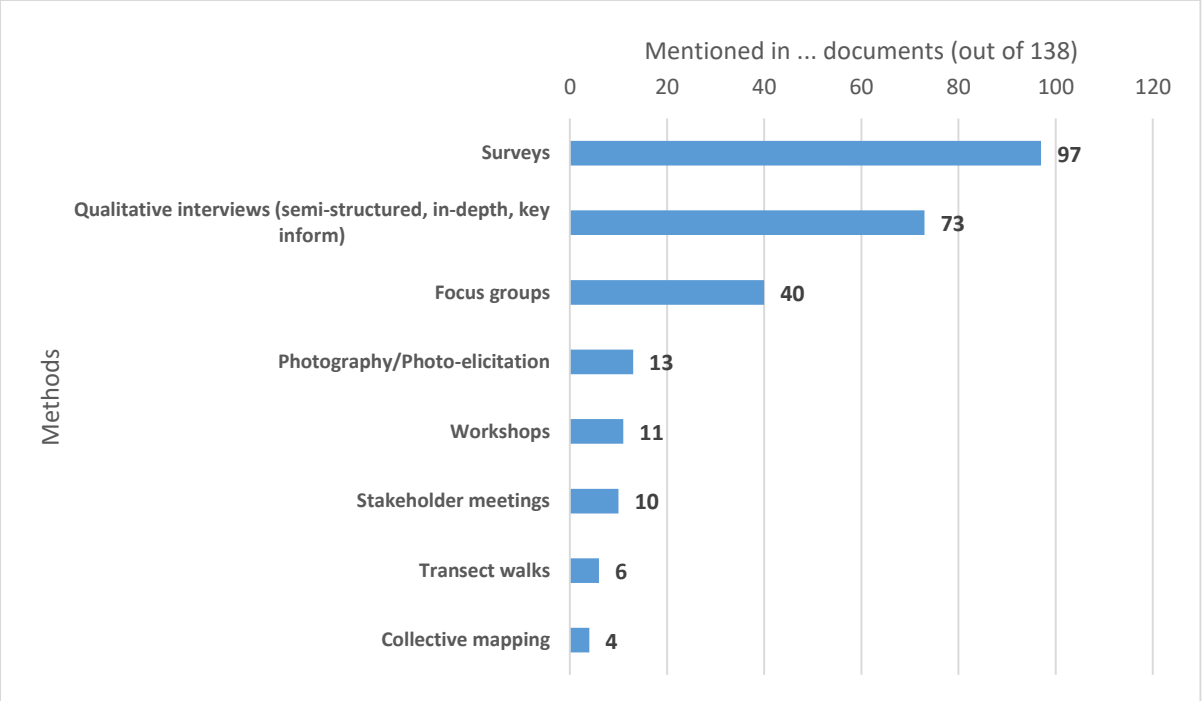
Annex 5 Type of geographical area the research areas are located in (multiple mentions possible per case study)



Annex 6 Types of flood mentioned in selected documents (multiple mentions possible in each document)

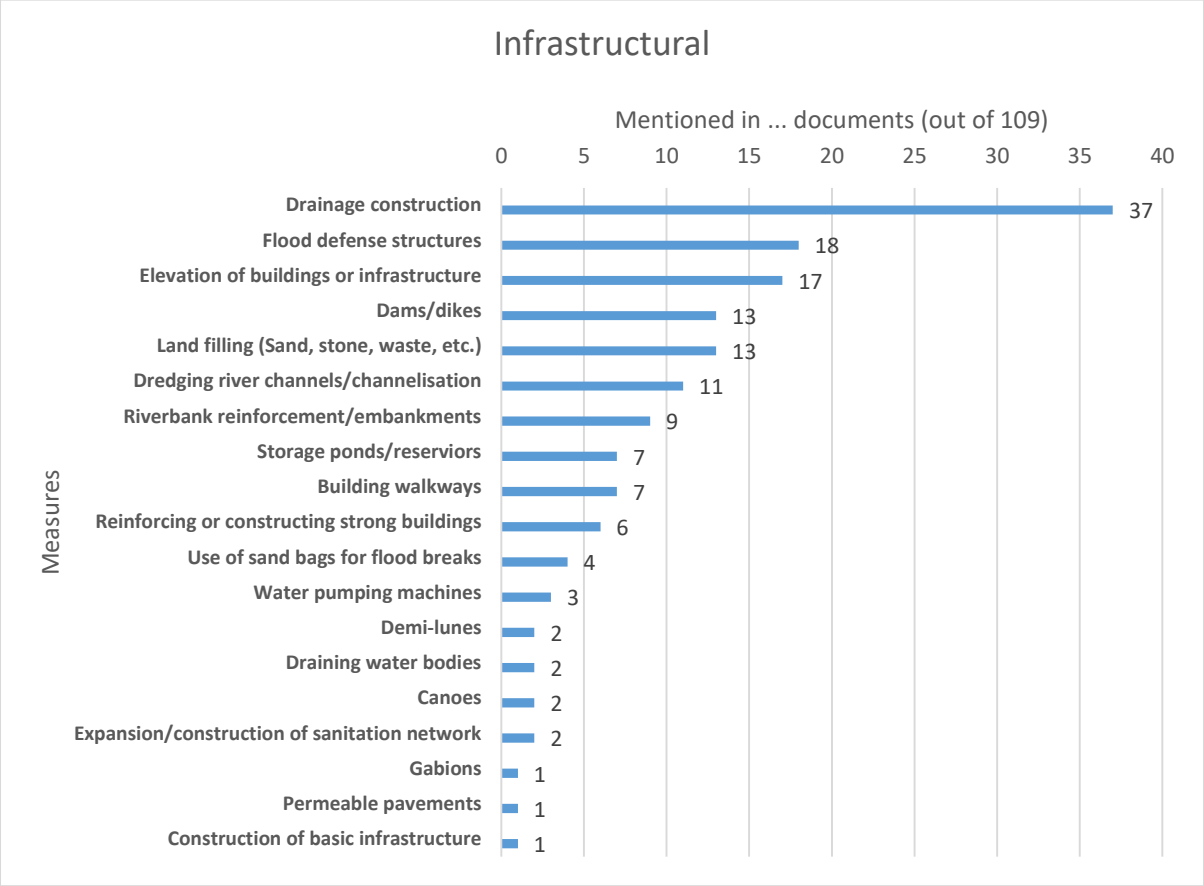


Annex 7 Types of methods used for primary data collection (multiple mentions possible in each document)

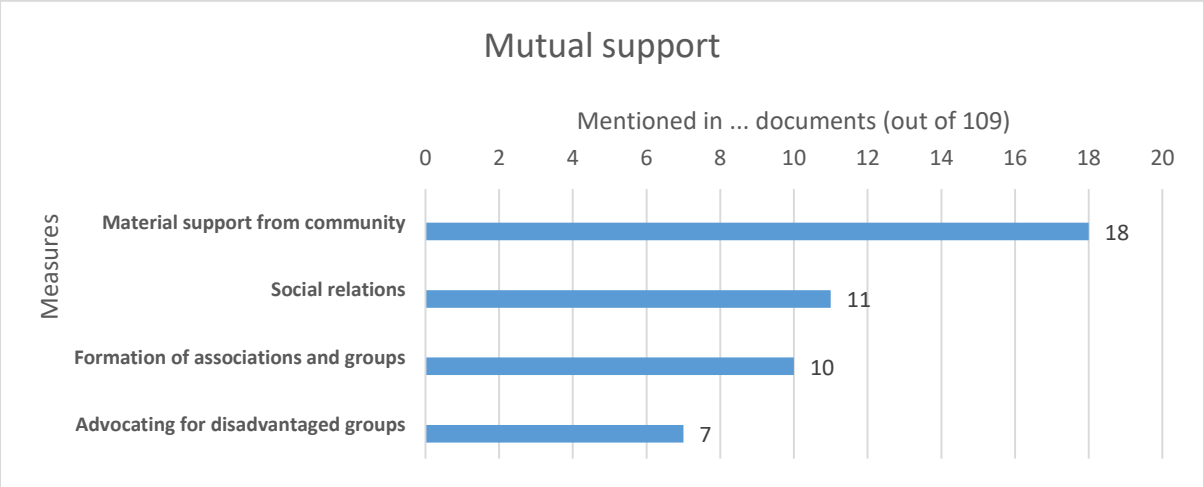


Annex 8 Summary of FRM measures before the onset of the most recent flood event grouped by categories

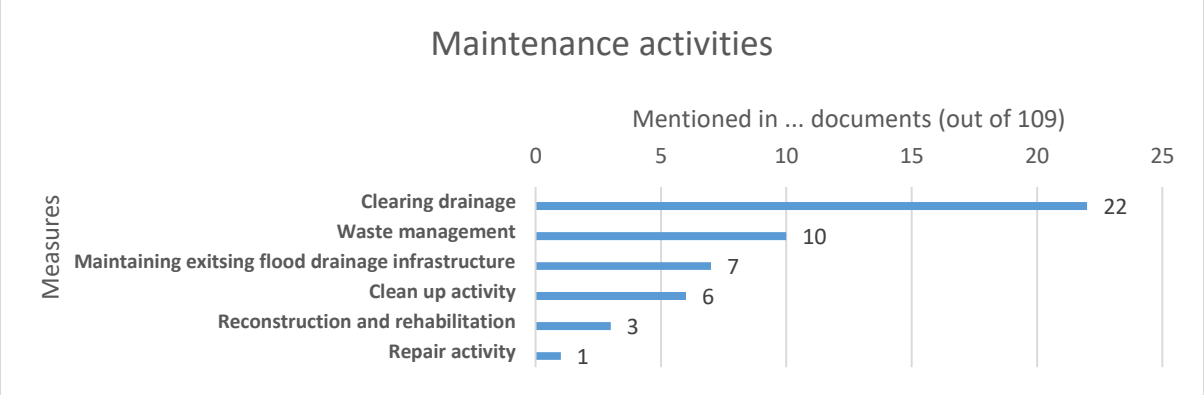
Infrastructural = *all measures that describe an infrastructural intervention to mitigate the hazard or to overcome its adverse impacts*



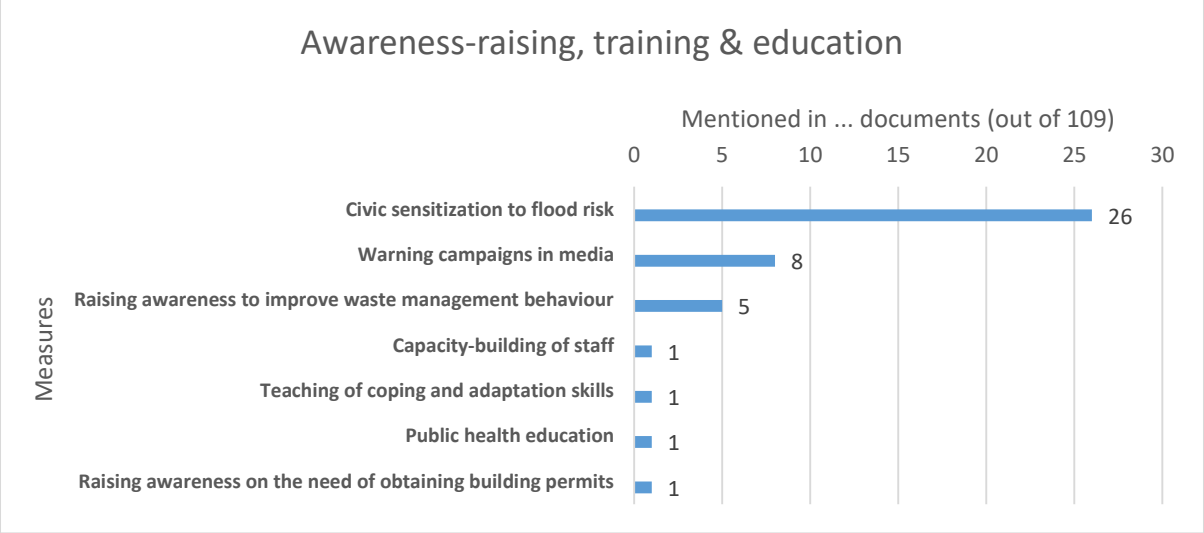
Mutual support = *all measures that summarize mutual support to reduce the risk of and overcome the adverse impacts of floods between people based on solidarity*



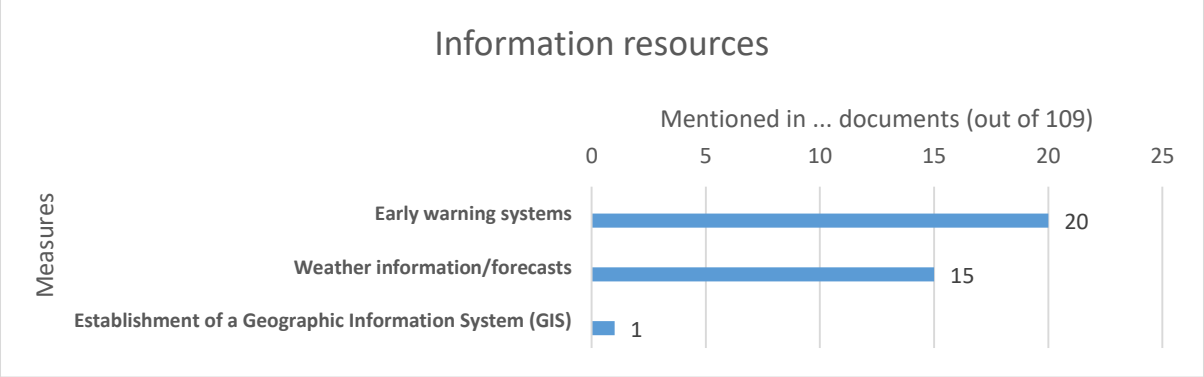
Maintenance activities = a*ll measures that aim at maintaining infrastructure, tools or performing clean up activities to better reduce the risk of or overcome the adverse impacts of floods*



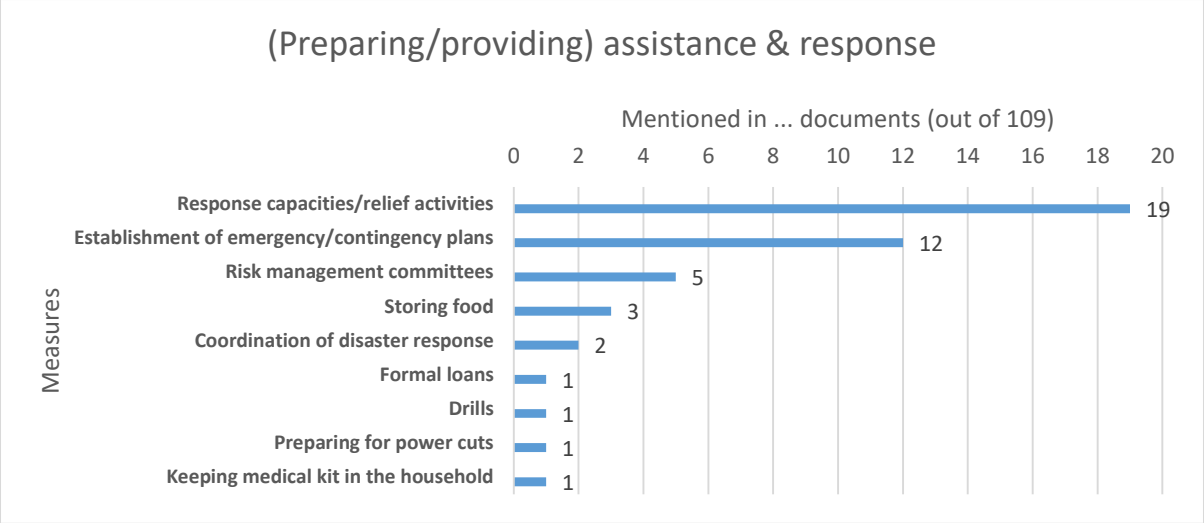
Awareness-raising, training & education = *all measures that aim at raising awareness of, providing training, and education on relevant topics to people at risk to reduce the risk of or to overcome the adverse impacts of floods*



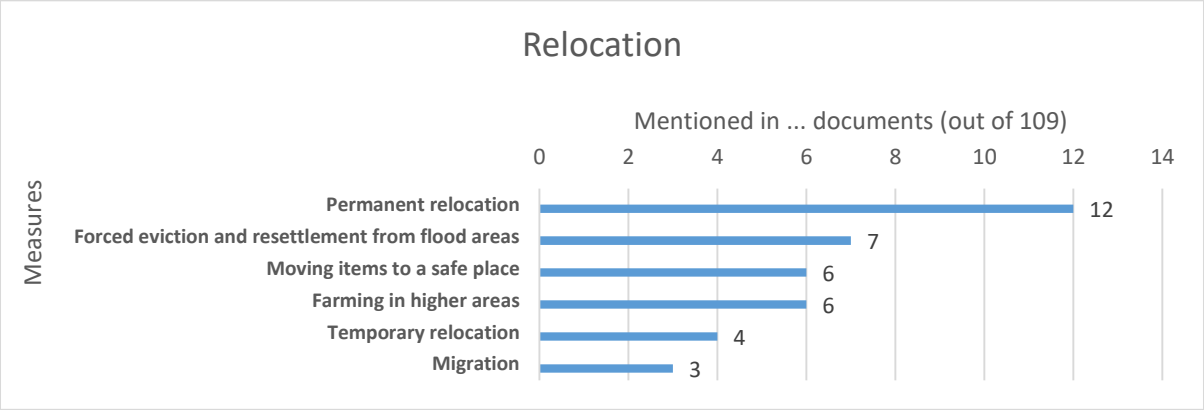
Information resources = *all measures that harness information channels and platforms to reduce flood risk or to overcome the adverse impacts of floods*



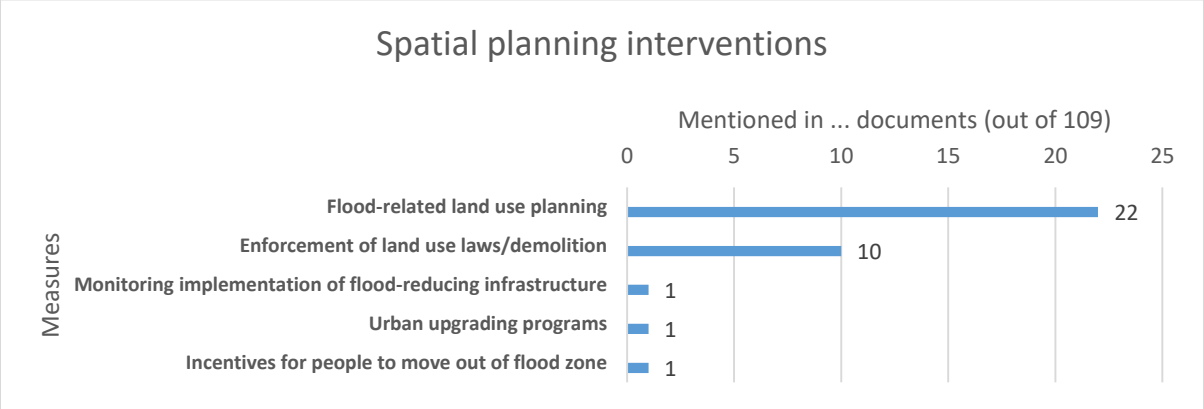
Preparing/providing assistance & response = *all measures that aim at preparing the provision of assistance or relief to reduce flood risk or at providing it to overcome the adverse impacts of floods*



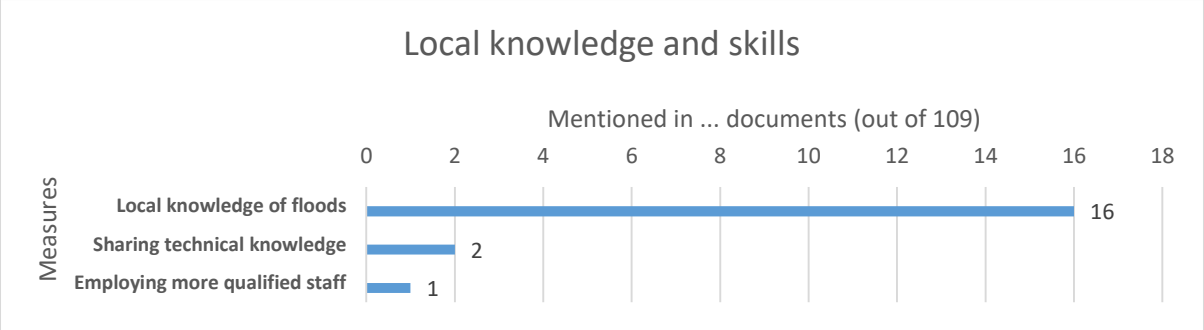
Relocation = *all measures that aim at reducing flood risk or overcoming the adverse impacts of floods through the movement of people or assets at risk out of the flood zone*



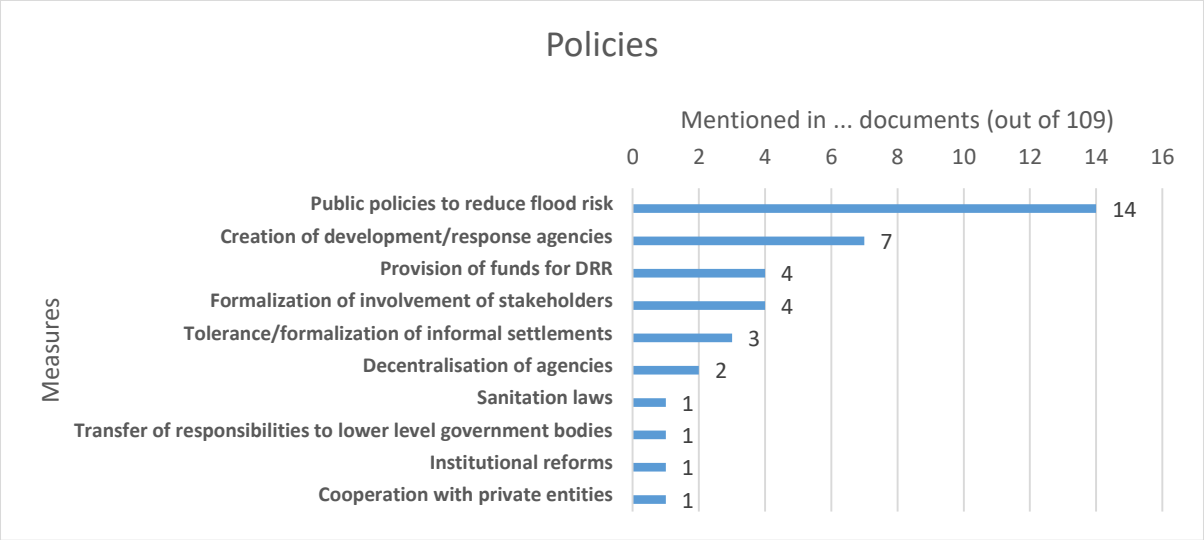
Spatial planning interventions = *All measures that aim at reducing flood risk by the application of spatial planning interventions or by the new creation of such*



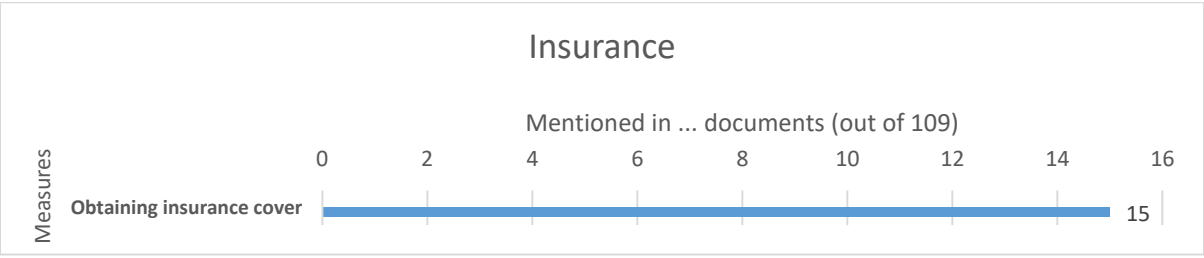
Local knowledge and skills = *the explicit consideration of place-specific knowledge of risk, possibilities to reduce it and to overcome its adverse effects*



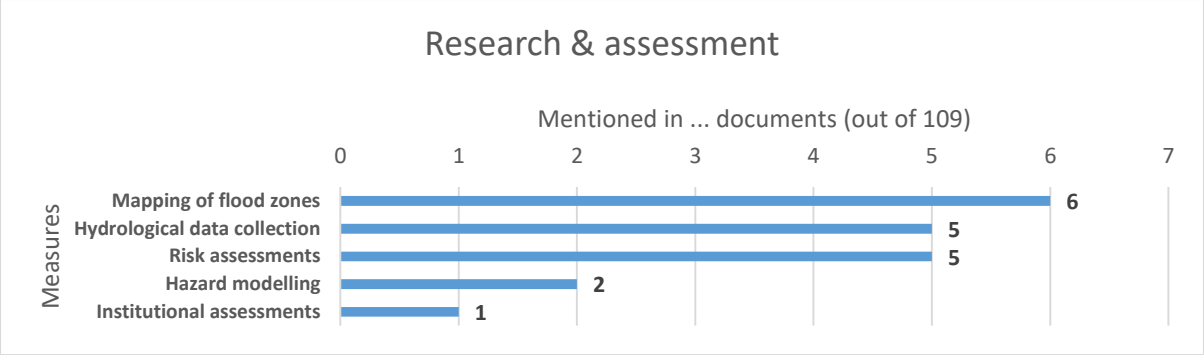
Policies = *All measures from the sphere of policies by which flood risk is intended to be reduced or adverse flood effects are attempted to be overcome*



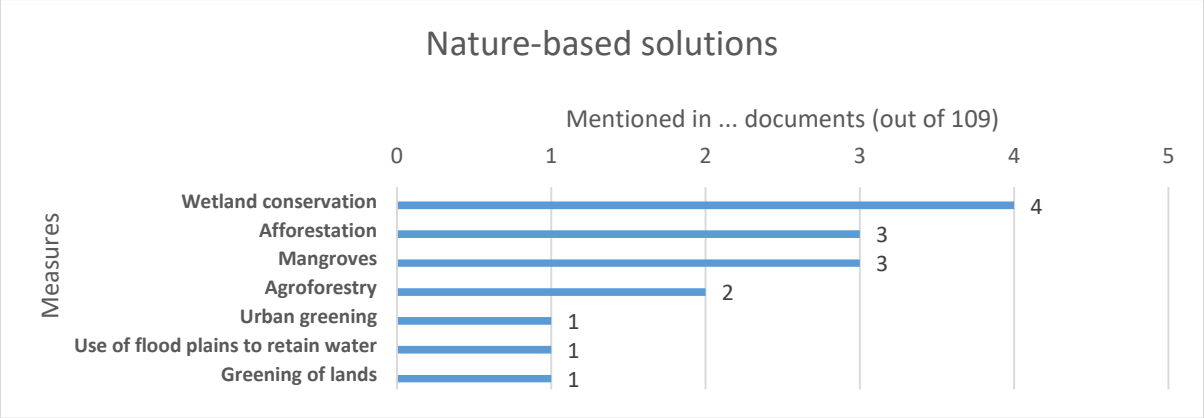
Insurance = a *formalized risk transfer arrangement with an insurance company as the risk carrier*



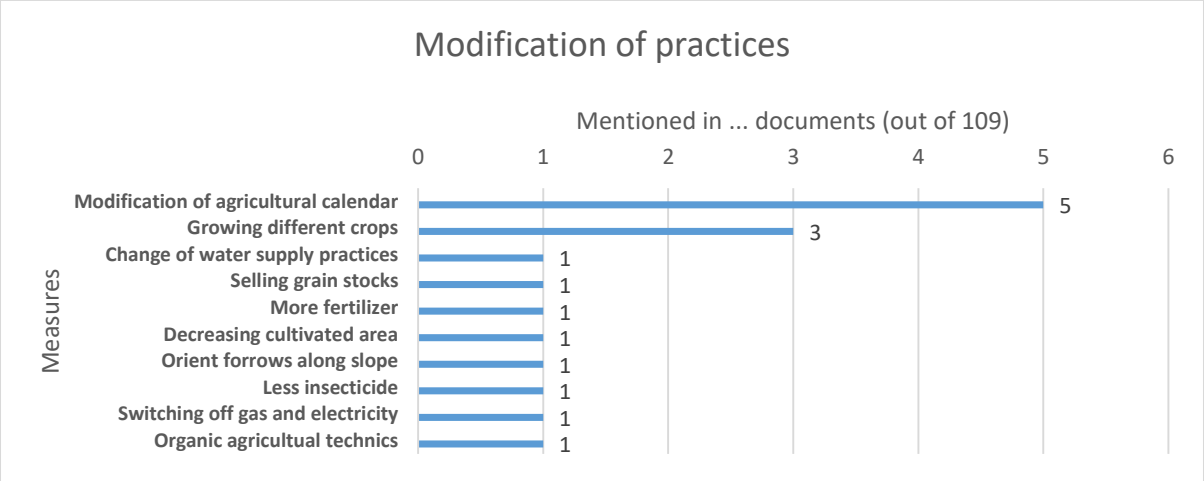
Research & assessment = *all measures that aim at generating information or knowledge to reduce flood risk or to alleviate the adverse effects of a flood event*



Nature-based solutions = *the use of ecosystem services to reduce flood risk or to alleviate the adverse impacts of a flood event*

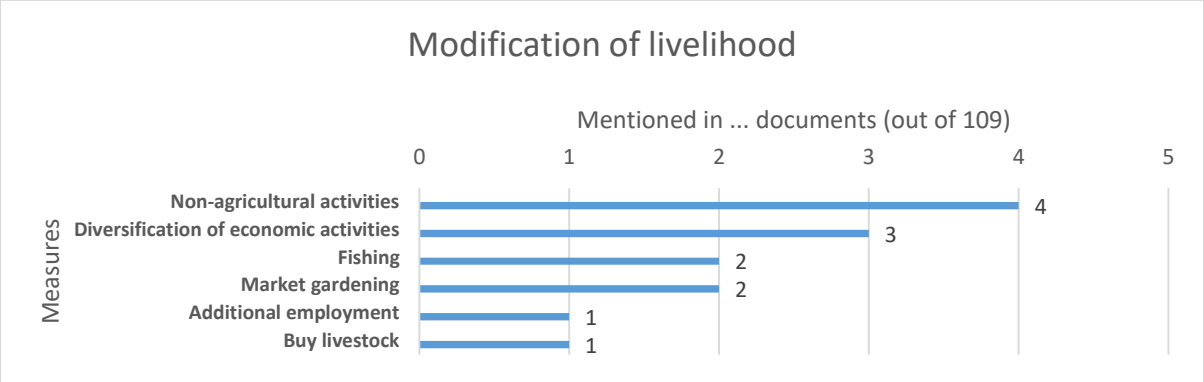


Modification of practices = *the modification of previously applied practices to reduce flood risk or to alleviate the adverse impacts of a flood event*

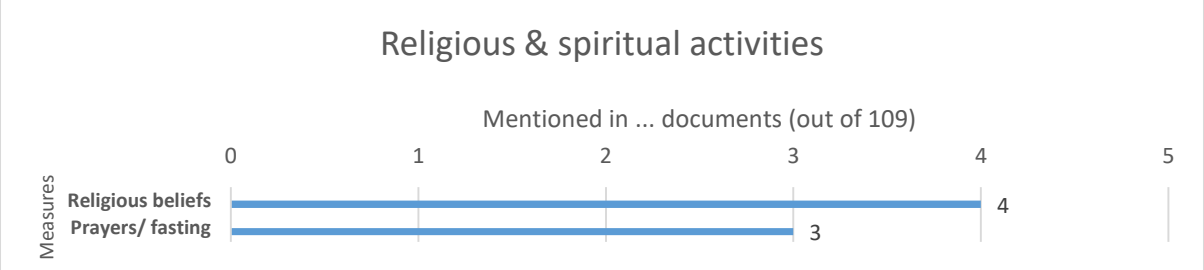


Risk retention = *retaining of resources to alleviate the adverse effects of unaddressed risk in case of flood event*

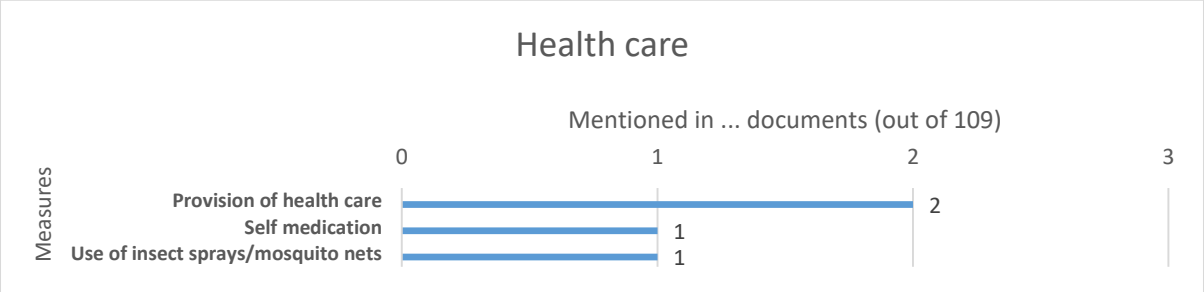
Modification of livelihood = *the modification of previously practiced livelihoods to reduce flood risk or to alleviate the adverse impacts of a flood event*



Religious & spiritual activities = *the use of religious or spiritual activities to perceive flood risk or to alleviate the adverse impacts of a flood event*

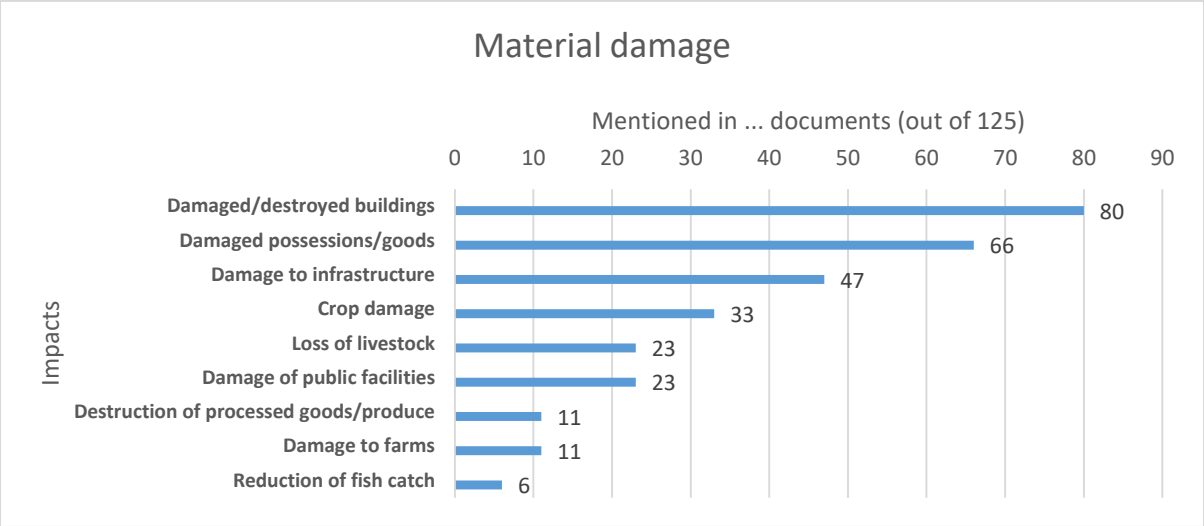


Health care = *the use of health care to reduce flood risk or to alleviate the adverse impacts of a flood event*

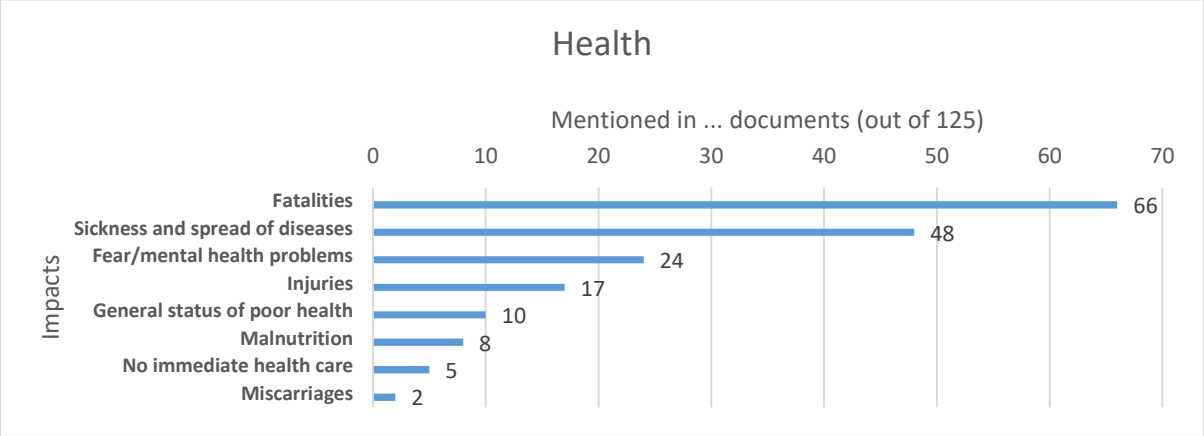


Annex 9 Impacts from residual flood risks from the most recent flood event

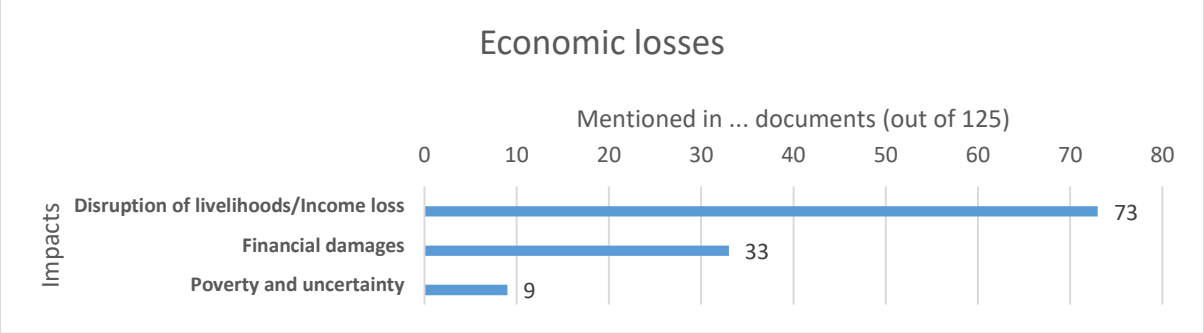
Material damage = *Damage of physical assets and resources used for livelihoods*



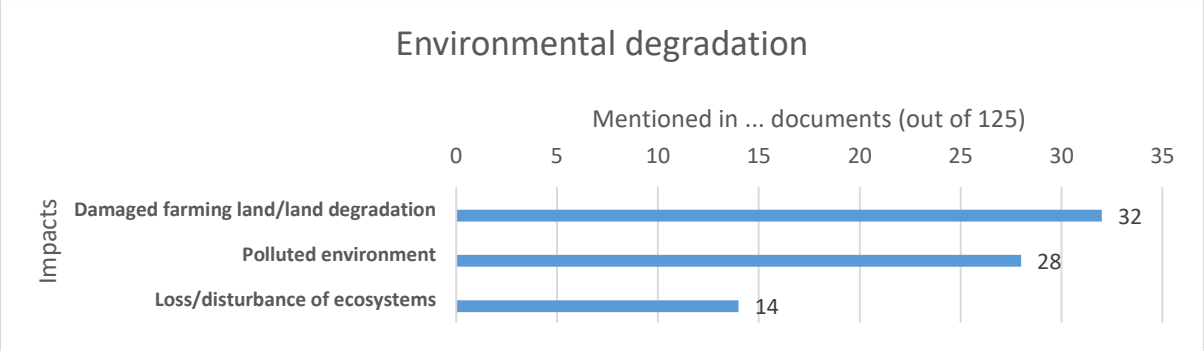
Health = *Adverse health impacts of the flood event*



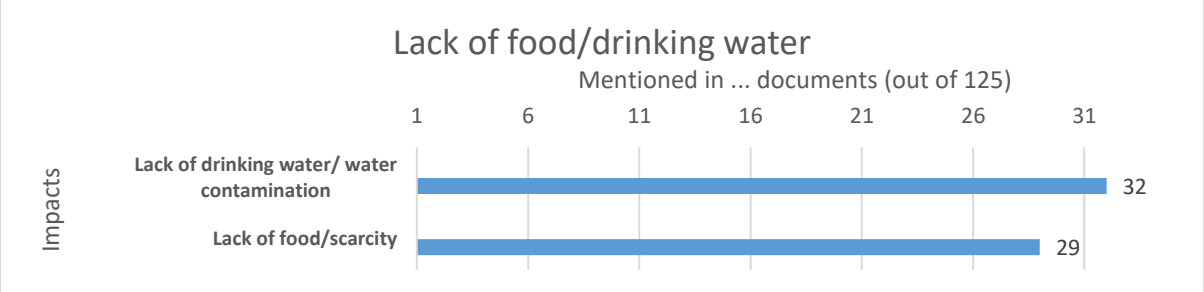
Economic losses = *Adverse effects on the economic situation of the population at risk and their cost of covering it*



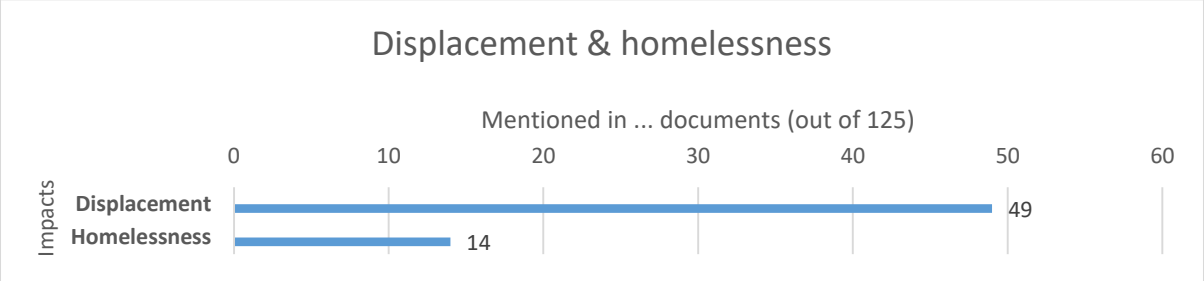
Environmental degradation = *Adverse flood impacts which lead to a degradation or pollution of the environment*



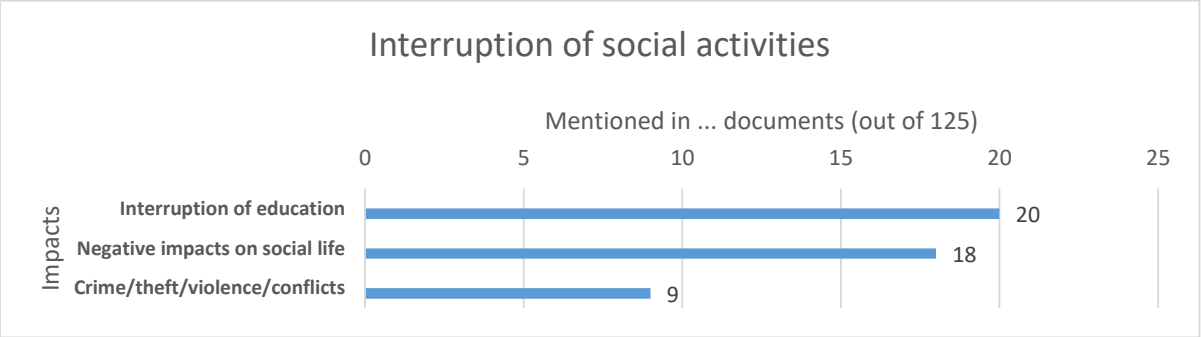
Lack of food/drinking water = *Adverse flood impacts leading to a scarcity of food or drinking water*



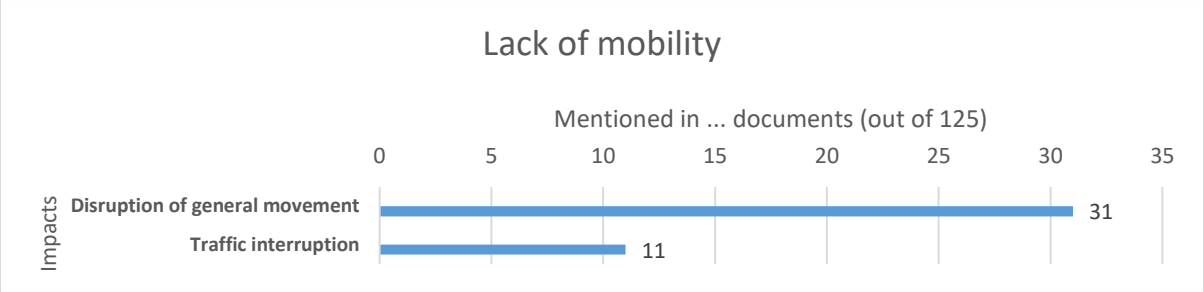
Displacement & homelessness = *Adverse flood impacts leading to a displacement from or a loss of the residence of the people at risk*



Interruption of social activities = *Adverse flood impacts disturbing common social activities*

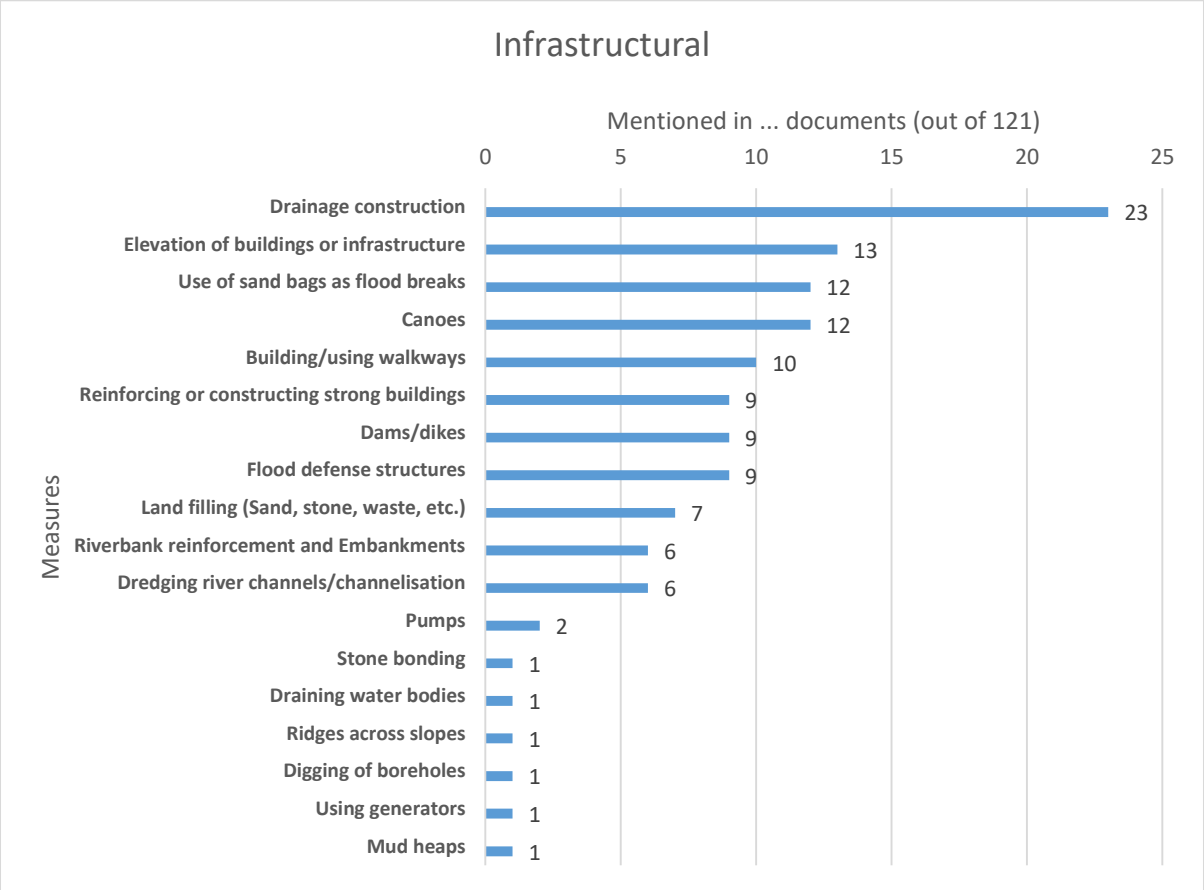


Lack of mobility = *Adverse flood impacts impairing the ability of people at risk to move*

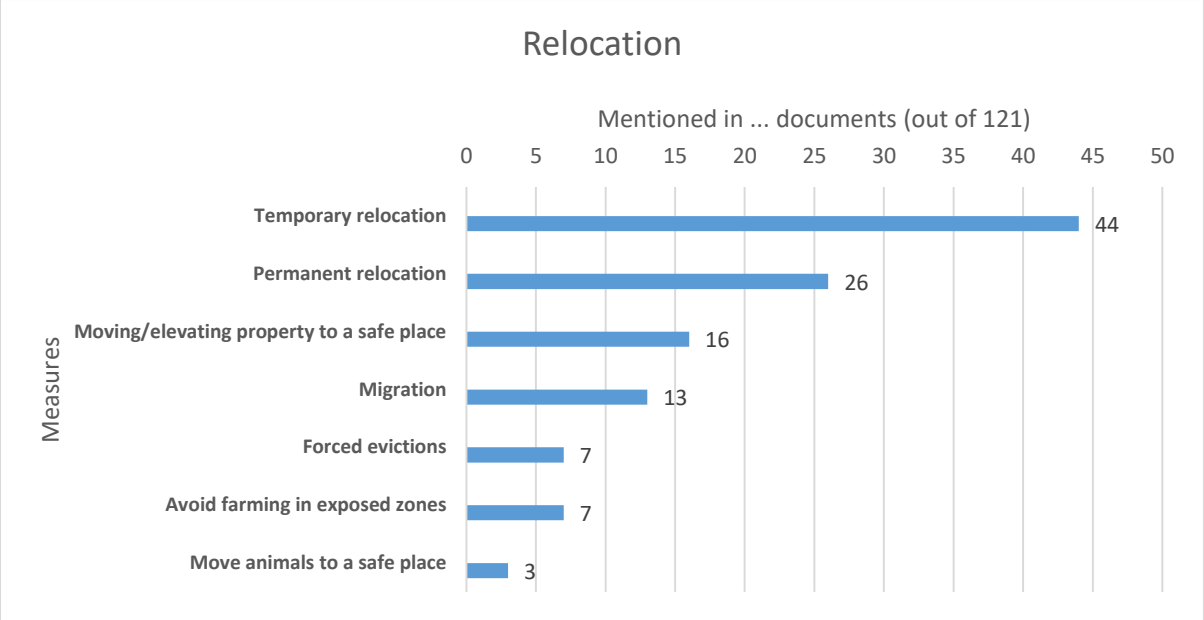


Annex 10 Measures to address impacts from residual flood risks after the onset of the most recent flood event

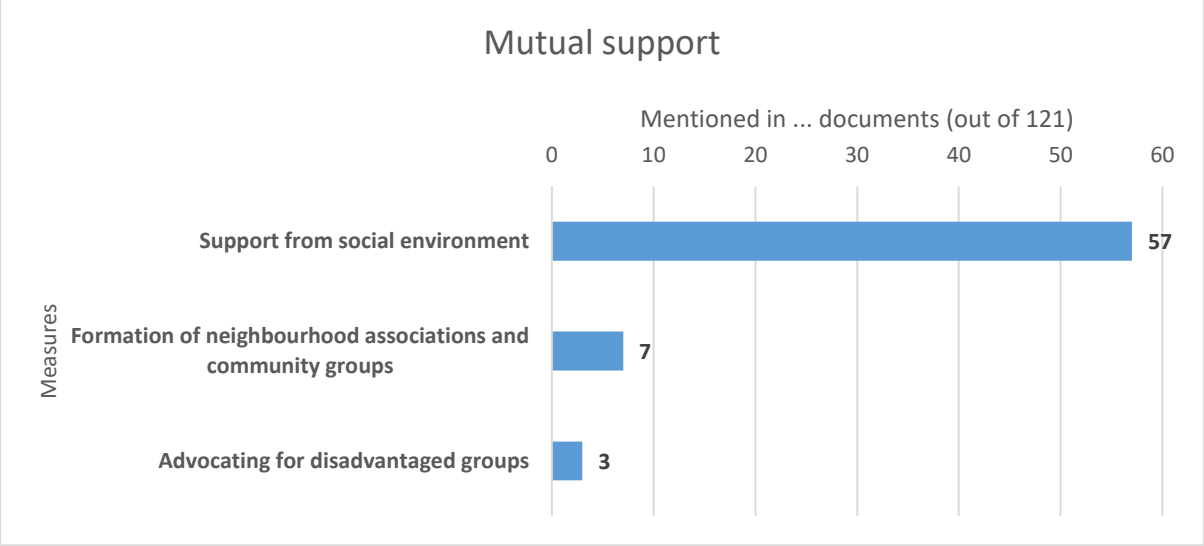
Infrastructural = *all measures that describe an infrastructural intervention to mitigate the hazard or to overcome its adverse impacts*



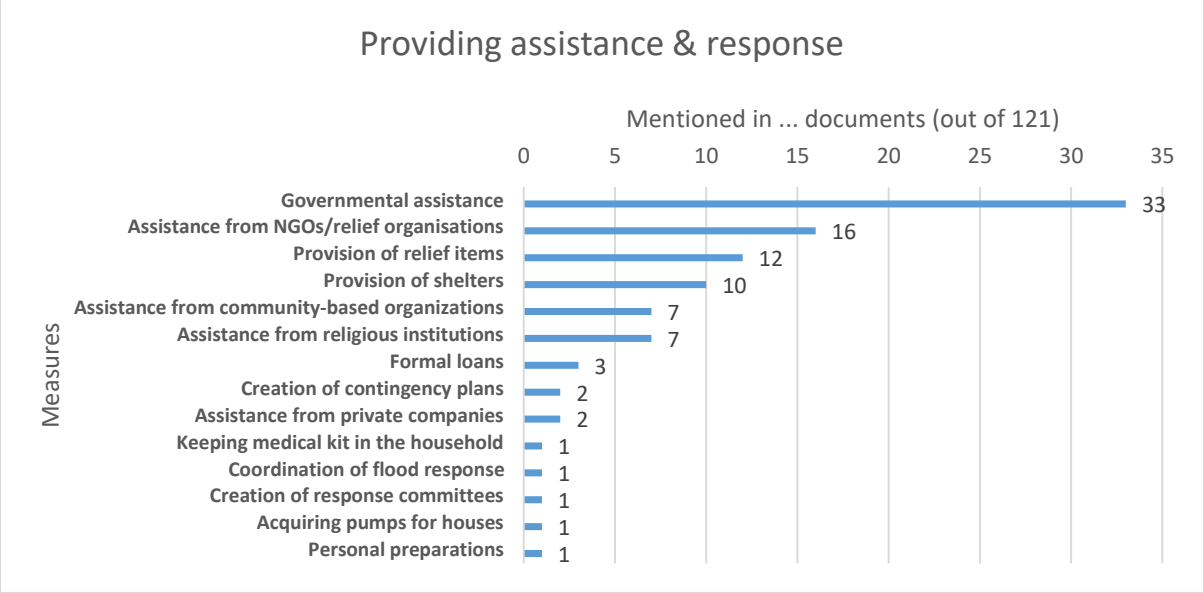
Relocation = *all measures that aim at reducing flood risk or overcoming the adverse impacts of floods through the movement of people or assets at risk out of the flood zone*



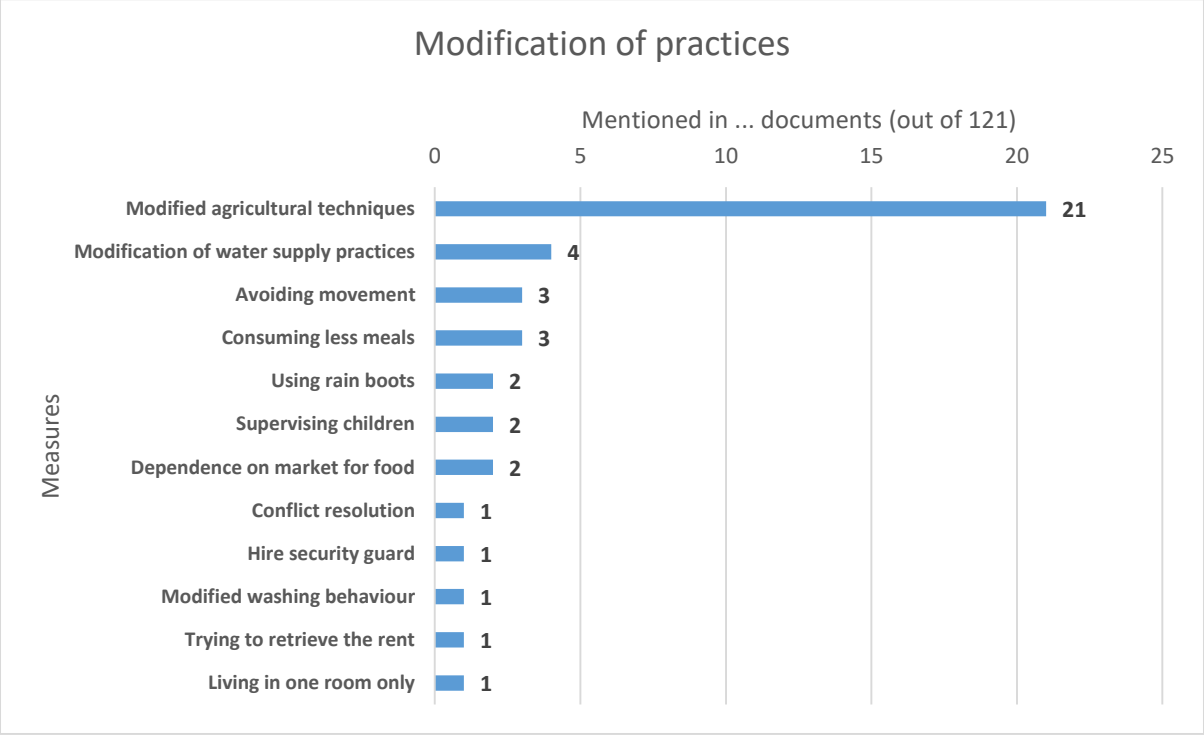
Mutual support = *all measures that summarize mutual support to reduce the risk of and overcome the adverse impacts of floods between people based on solidarity*



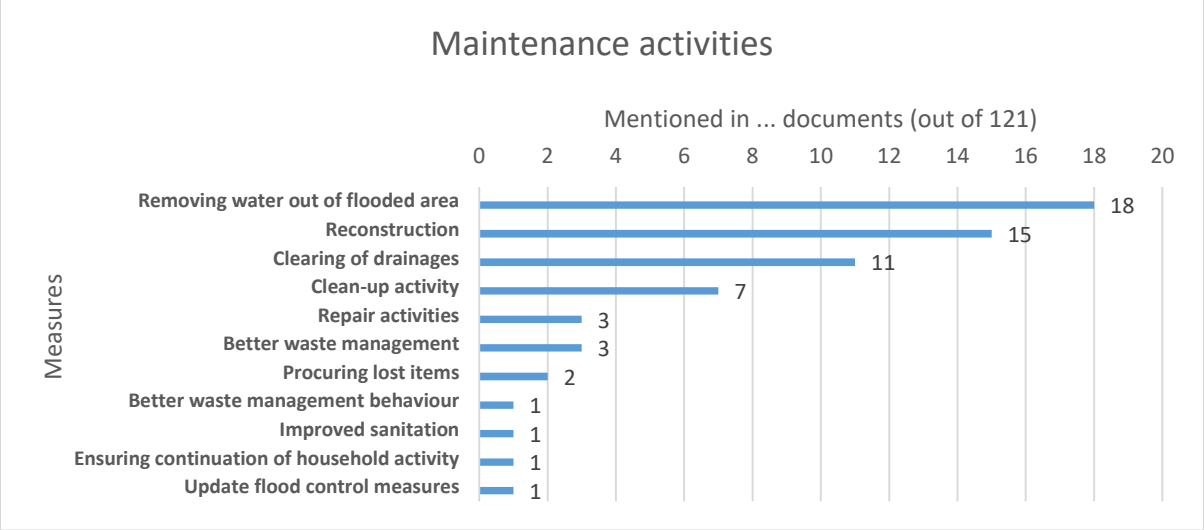
Providing assistance & response = *all measures that aim at providing assistance or relief to overcome the adverse impacts of floods*



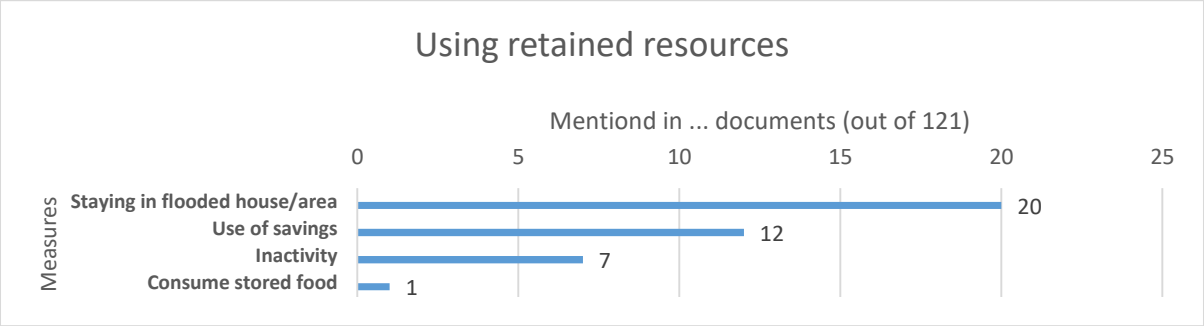
Modification of practices = *the modification of previously applied practices to reduce flood risk or to alleviate the adverse impacts of a flood event*



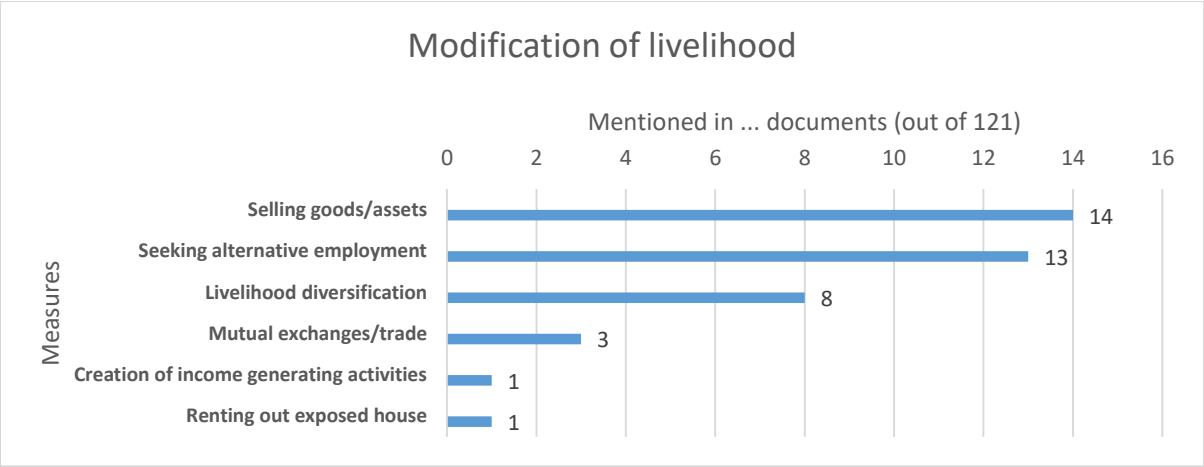
Maintenance activities = *all measures that aim at maintaining infrastructure, tools or performing clean up activities to better reduce the risk of or overcome the adverse impacts of floods*



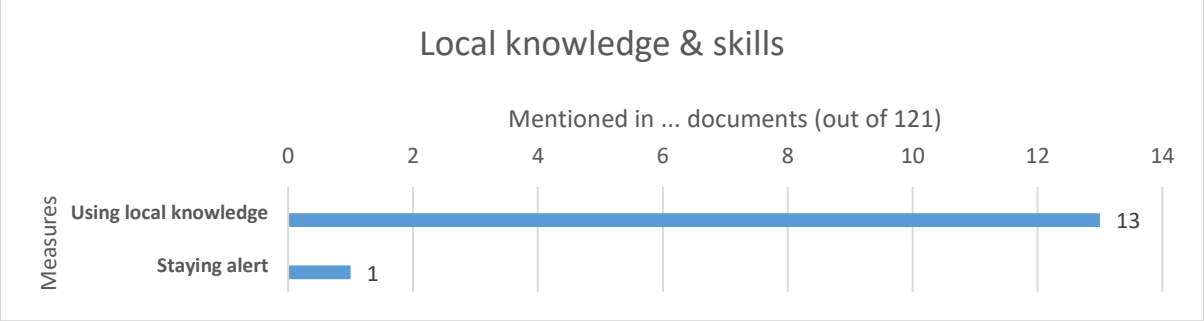
Using retained resources = using *retained resources to alleviate the adverse effects of unaddressed risk in case of a flood event*



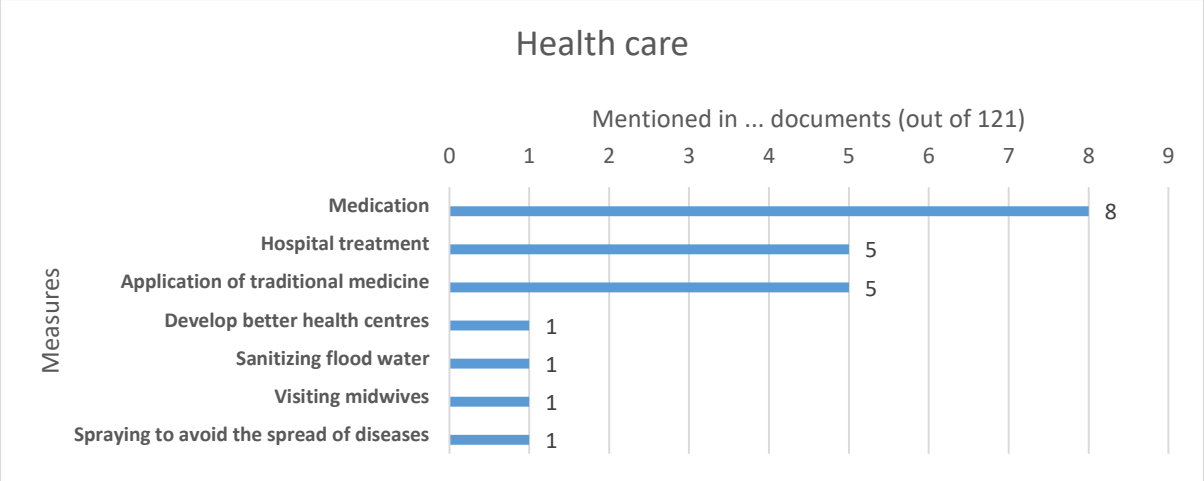
Modification of livelihood = *the modification of previously practiced livelihoods to reduce flood risk or to alleviate the adverse impacts of a flood event*



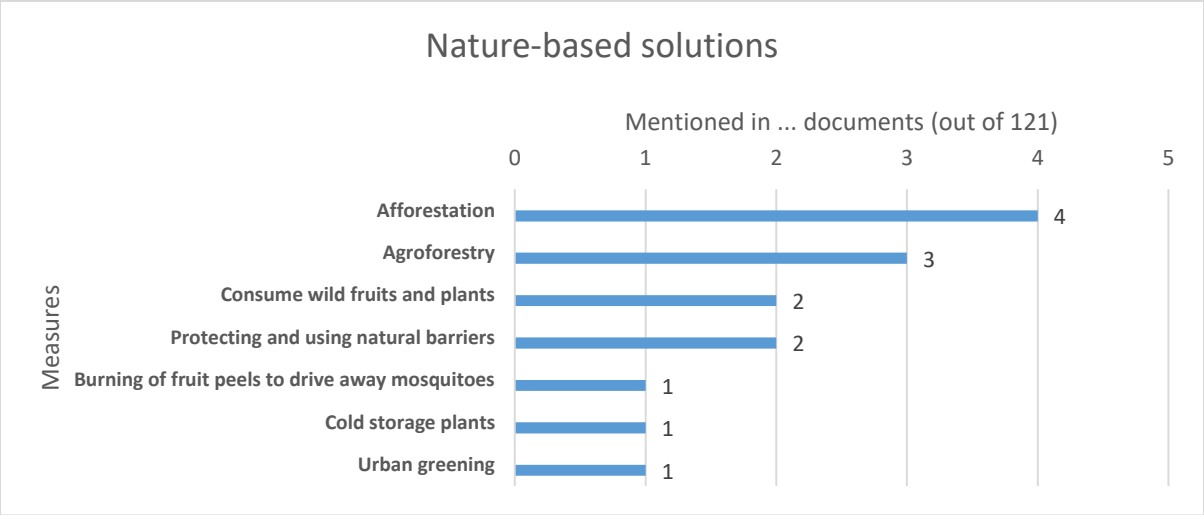
Local knowledge & skills = *the explicit consideration of place-specific knowledge of risk, possibilities to reduce it and to overcome its adverse effects*



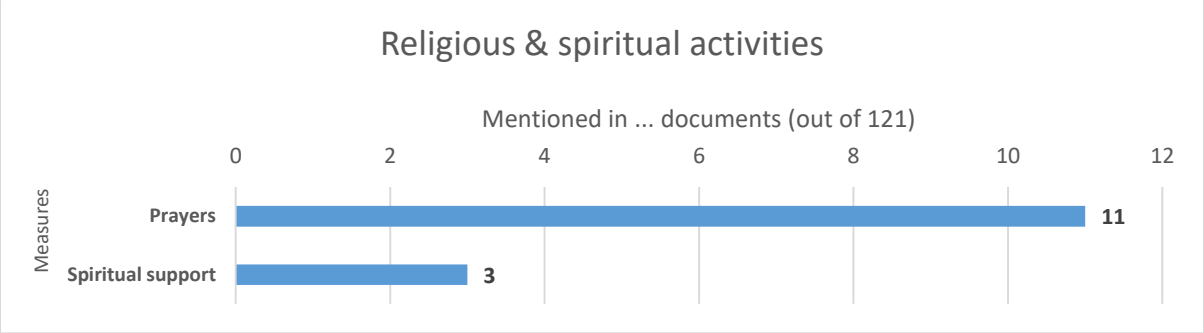
Health care = *the use of health care to reduce flood risk or to alleviate the adverse impacts of a flood event*



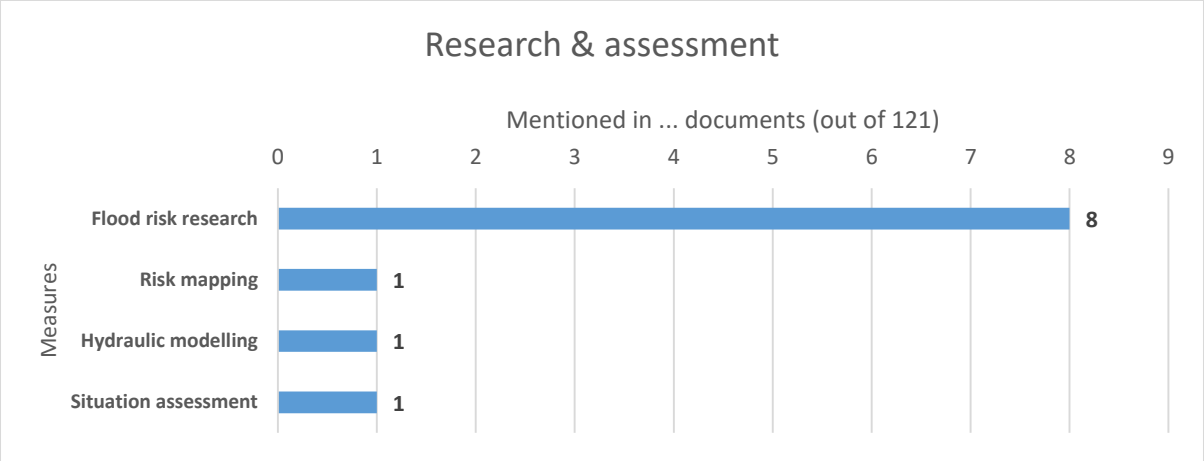
Nature-based solutions = *the use of ecosystem services to reduce flood risk or to alleviate the adverse impacts of a flood event*



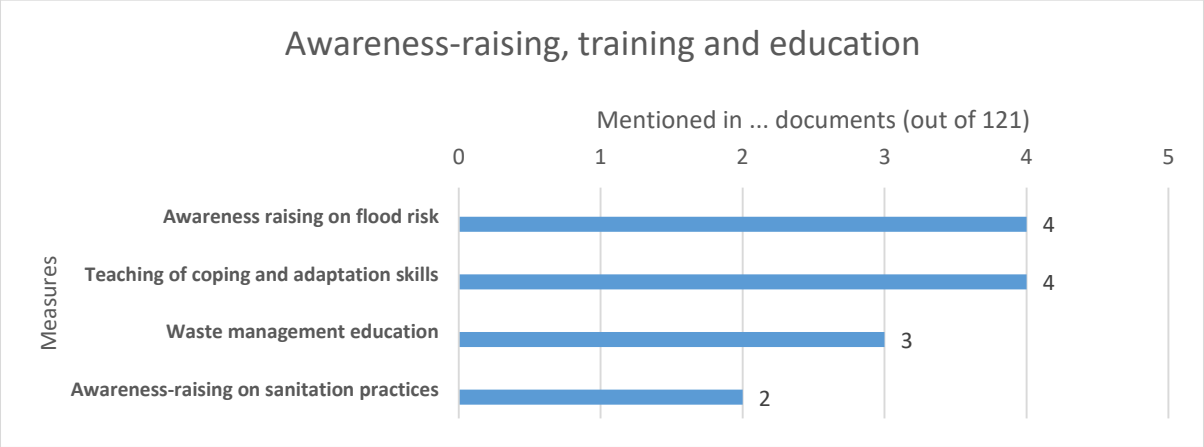
Religious & spiritual activities = *the use of religious or spiritual activities to perceive flood risk or to alleviate the adverse impacts of a flood event*



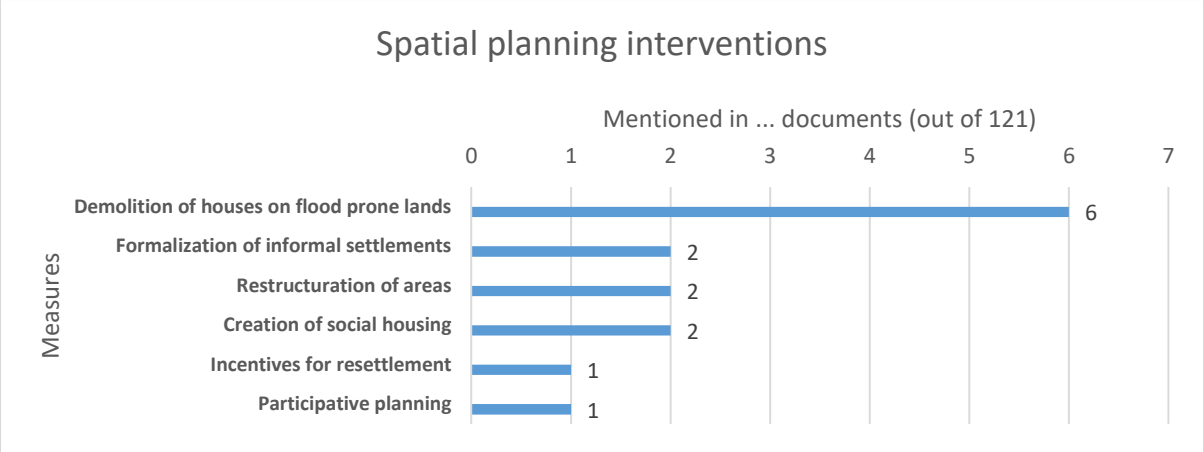
Research & assessment = *all measures that aim at generating information or knowledge to reduce flood risk or to alleviate the adverse effects of a flood event*



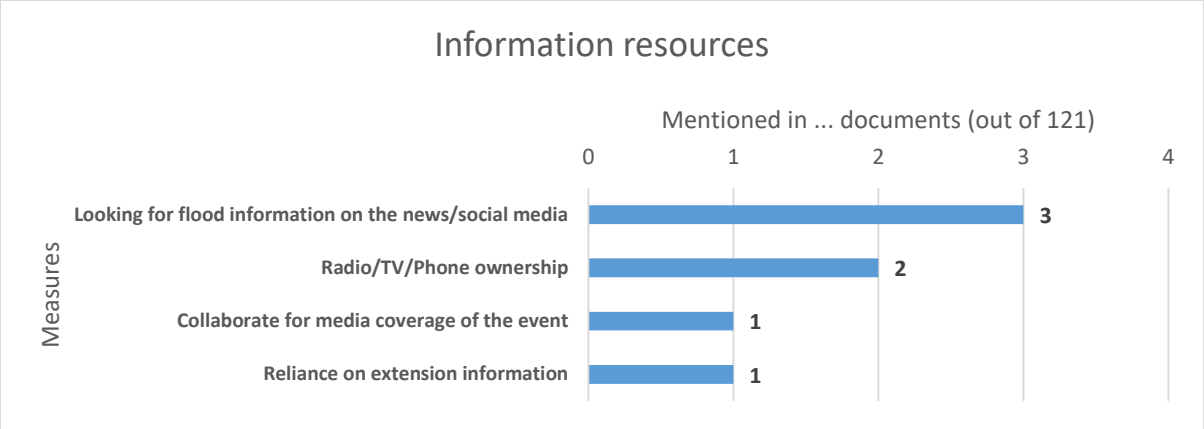
Awareness-raising, training and education = *all measures that aim at raising awareness of, providing training, and education on relevant topics to people at risk to reduce the risk of or to overcome the adverse impacts of floods*



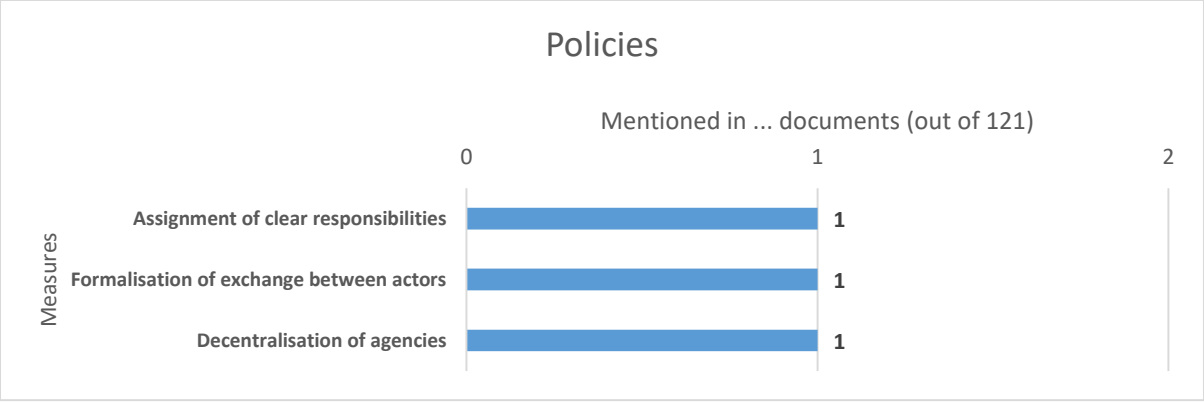
Spatial planning interventions = *All measures that aim at reducing flood risk by the application of spatial planning interventions or by the new creation of such*



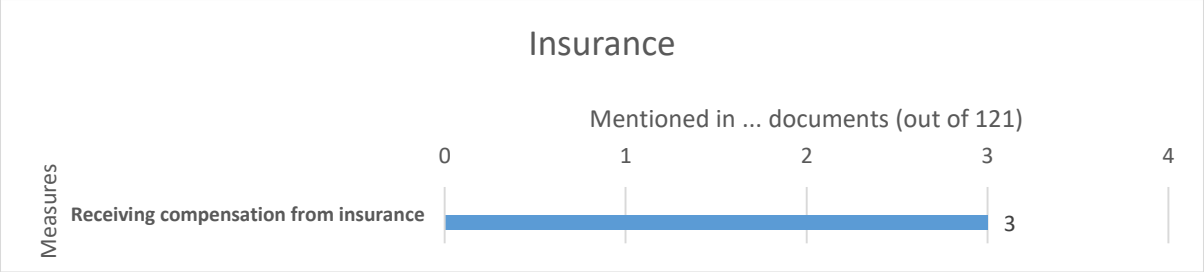
Information resources = *all measures that harness information channels and platforms to reduce flood risk or to overcome the adverse impacts of floods*



Policies = *all measures from the sphere of policies by which flood risk is intended to be reduced or adverse flood effects are attempted to be overcome*

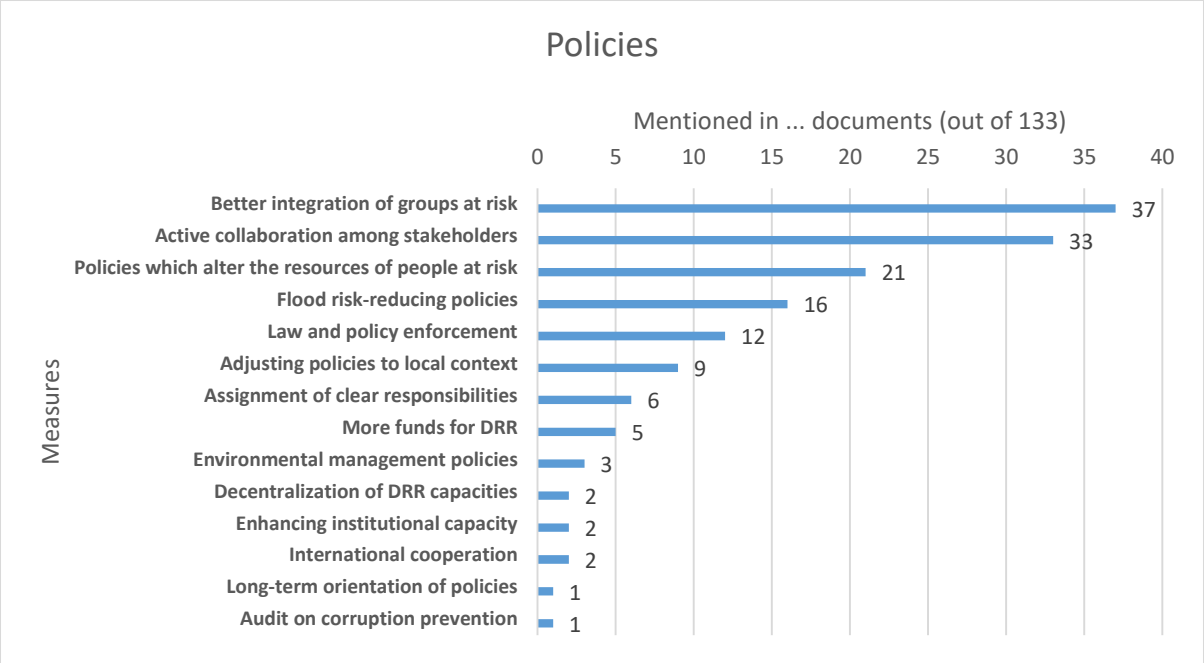


Insurance = a *formalized risk transfer arrangement with an insurance company as the risk carrier*

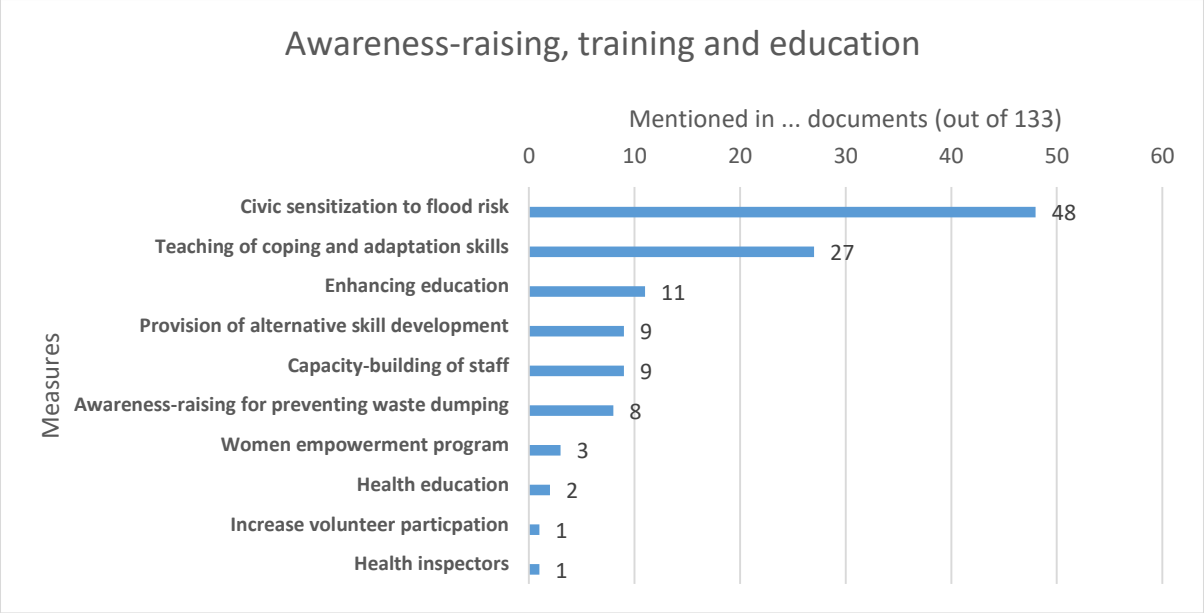


Annex 11 Recommendations in selected case studies to further reduce residual flood risk

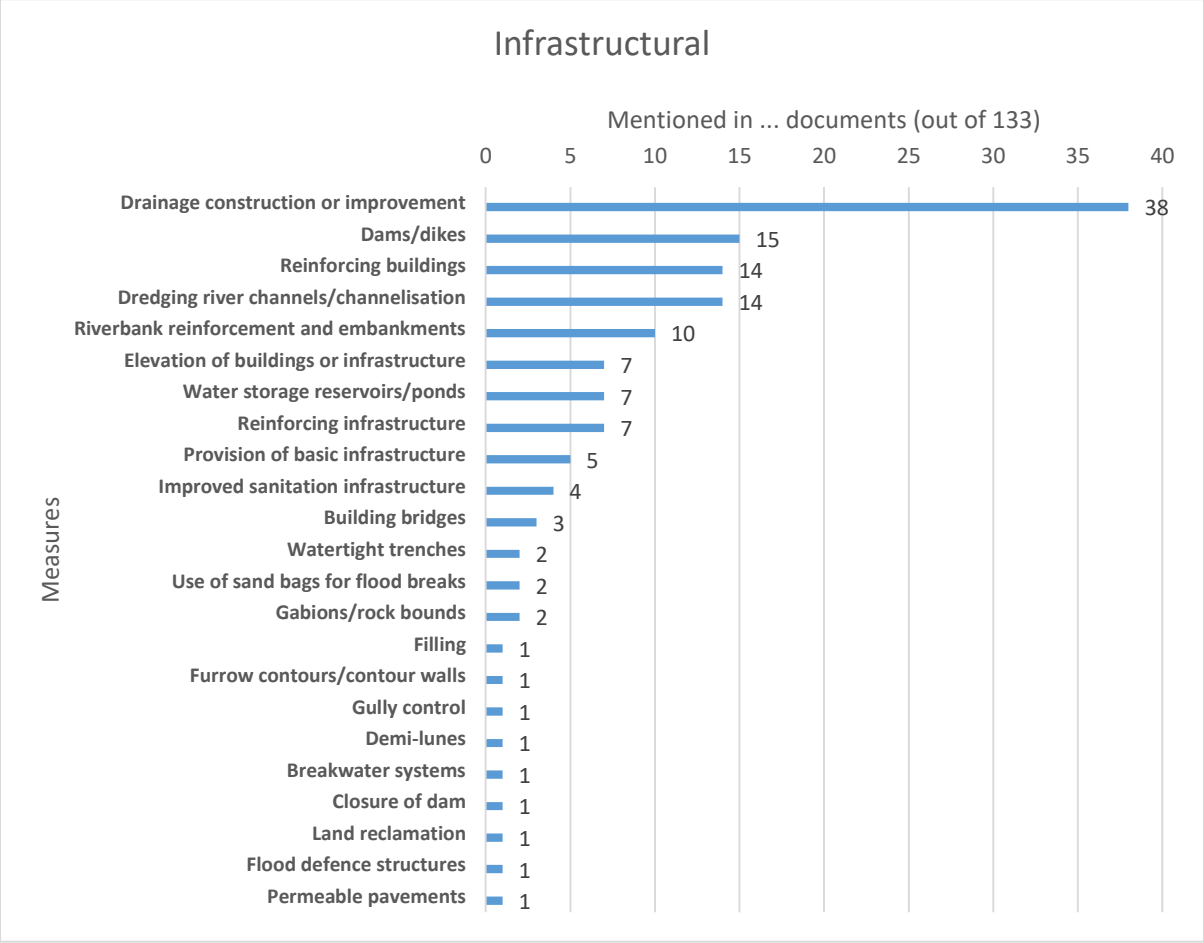
Policies = *All measures from the sphere of policies by which flood risk is intended to be reduced or adverse flood effects are attempted to be overcome*



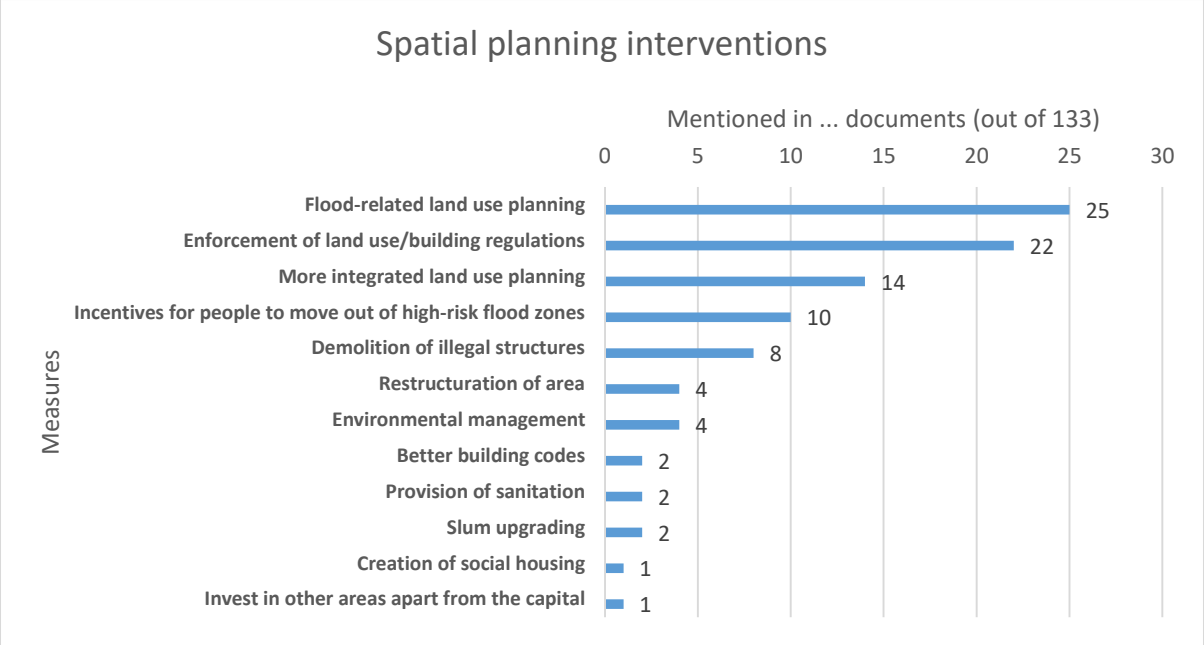
Awareness-raising, training and education = *all measures that aim at raising awareness of, providing training, and education on relevant topics to people at risk to reduce the risk of or to overcome the adverse impacts of floods*



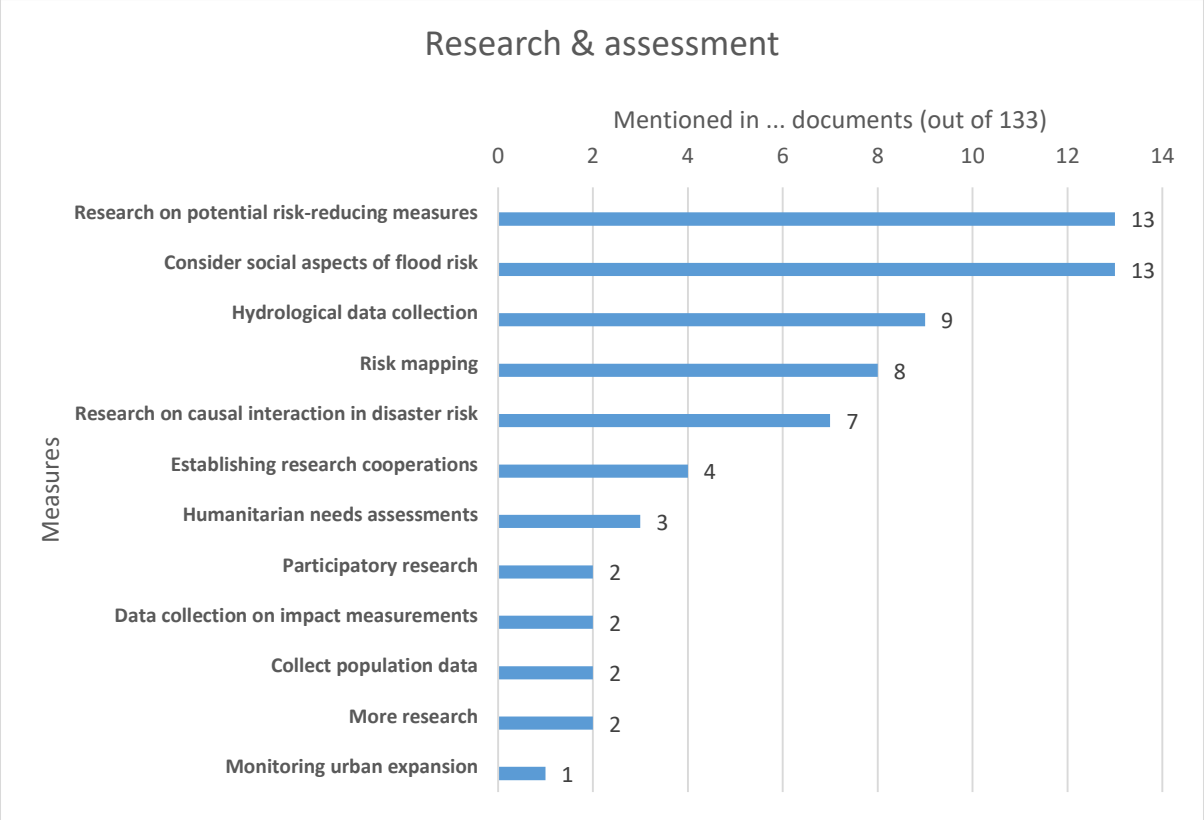
Infrastructural = *all measures that describe an infrastructural intervention to mitigate the hazard or to overcome its adverse impacts*



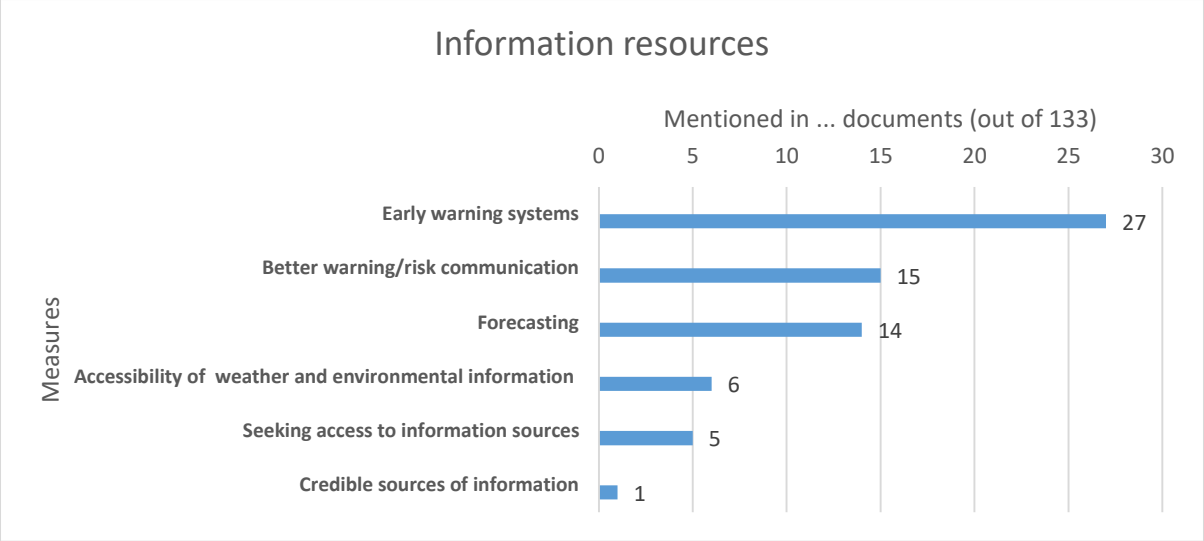
Spatial planning interventions = *All measures that aim at reducing flood risk by the application of spatial planning interventions or by the new creation of such*



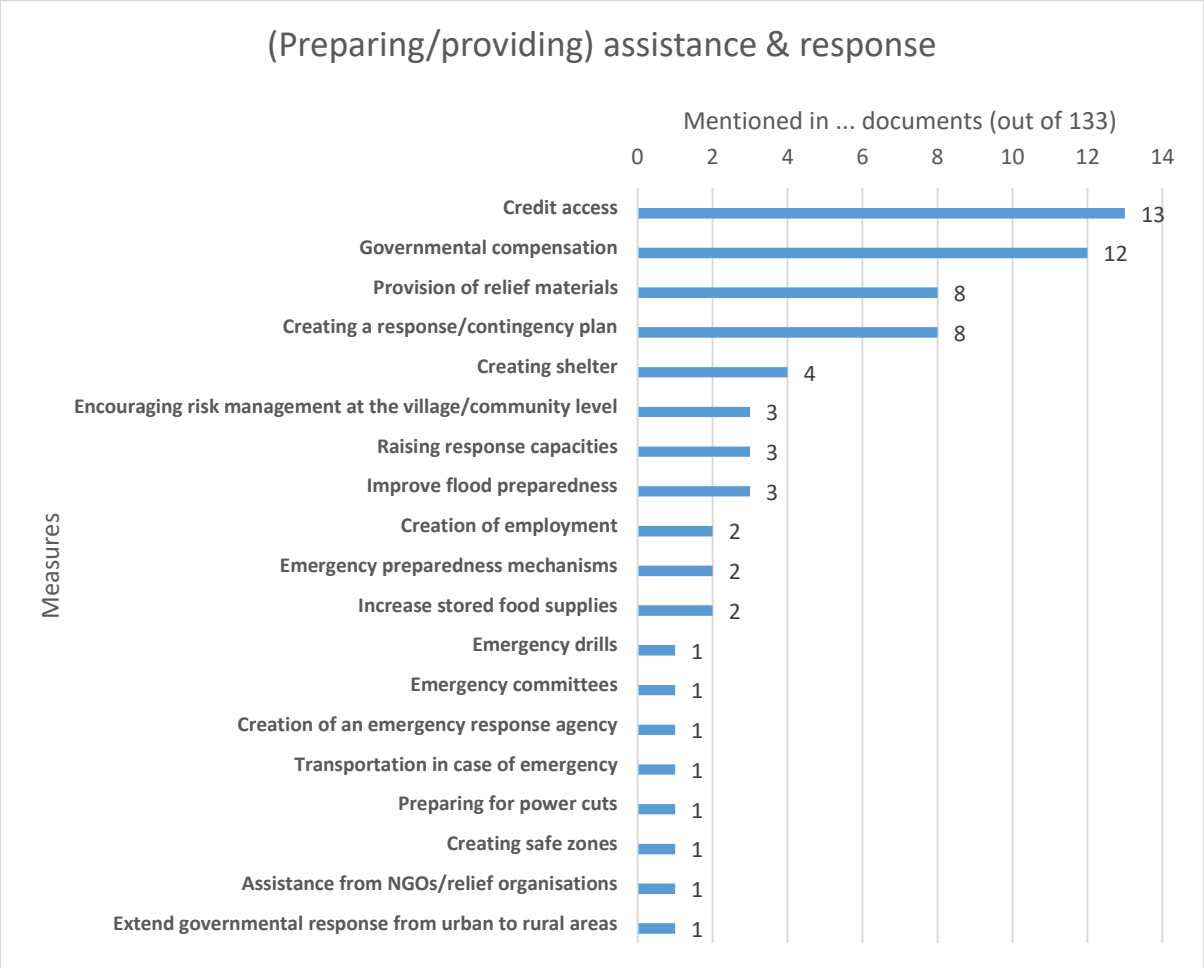
Research & assessment = *all measures that aim at generating information or knowledge to reduce flood risk or to alleviate the adverse effects of a flood event*



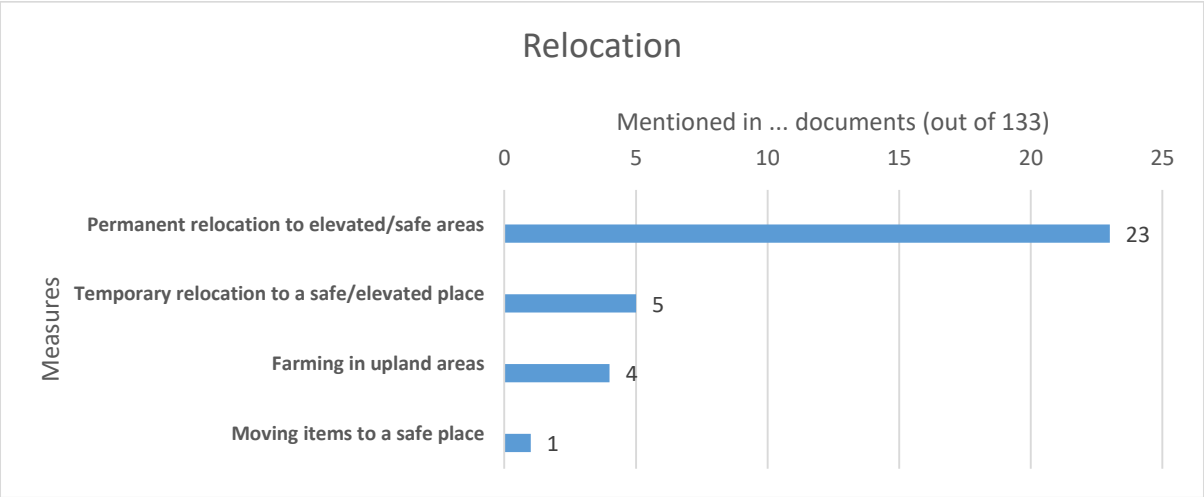
Information resources = *all measures that harness information channels and platforms to reduce flood risk or to overcome the adverse impacts of floods*



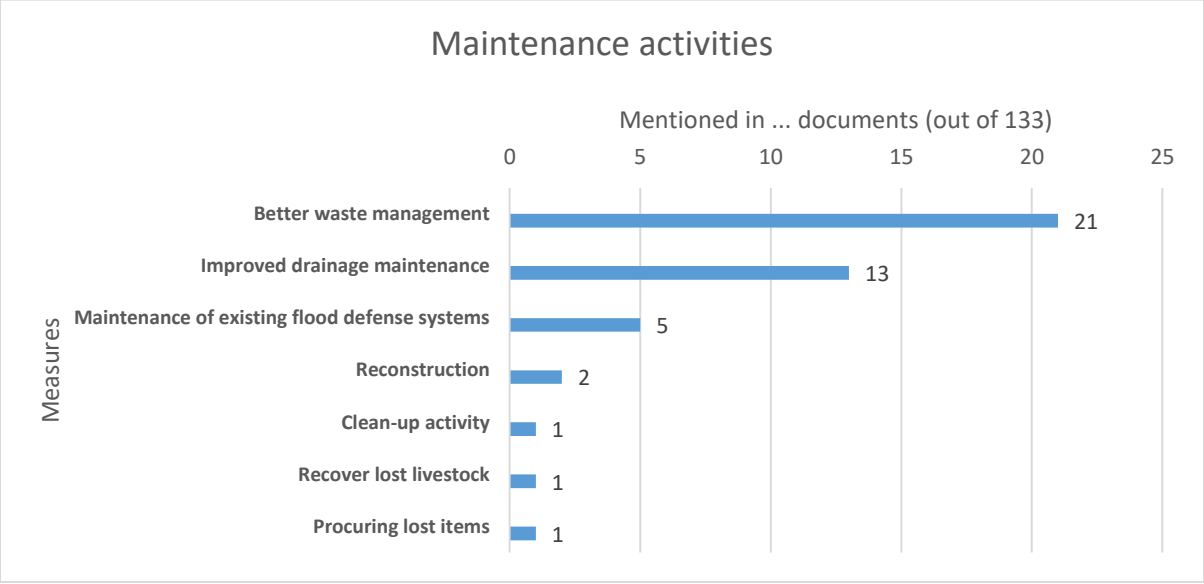
(Preparing/providing) assistance & response = *all measures that aim at preparing the provision of assistance or relief to reduce flood risk or at providing it to overcome the adverse impacts of floods*



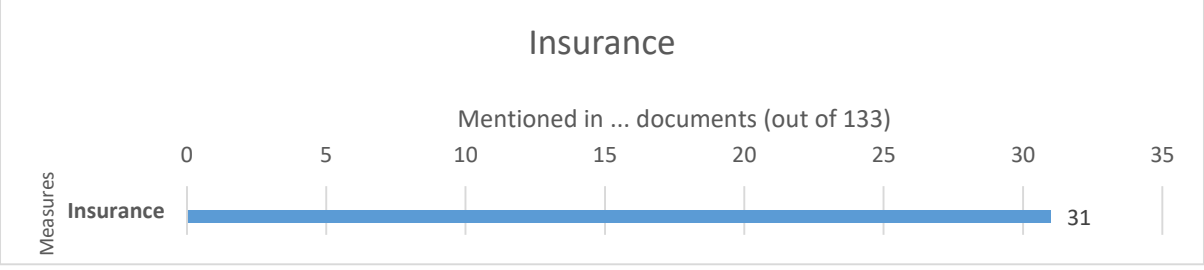
Relocation = *all measures that aim at reducing flood risk or overcoming the adverse impacts of floods through the movement of people or assets at risk out of the flood zone*



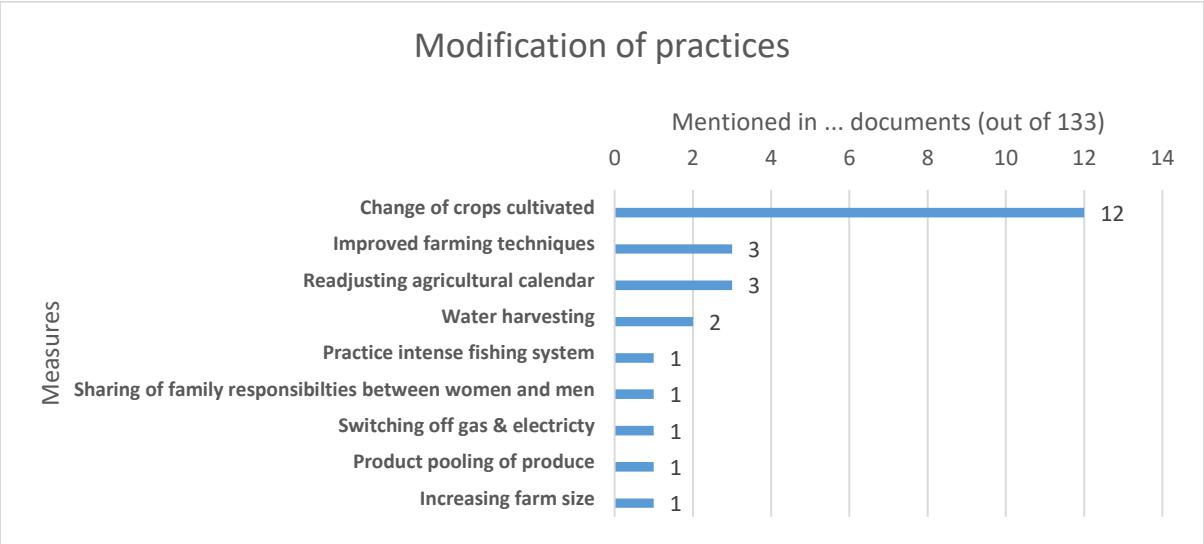
Maintenance activities = *all measures that aim at maintaining infrastructure, tools or performing clean up activities to better reduce the risk of or overcome the adverse impacts of floods*



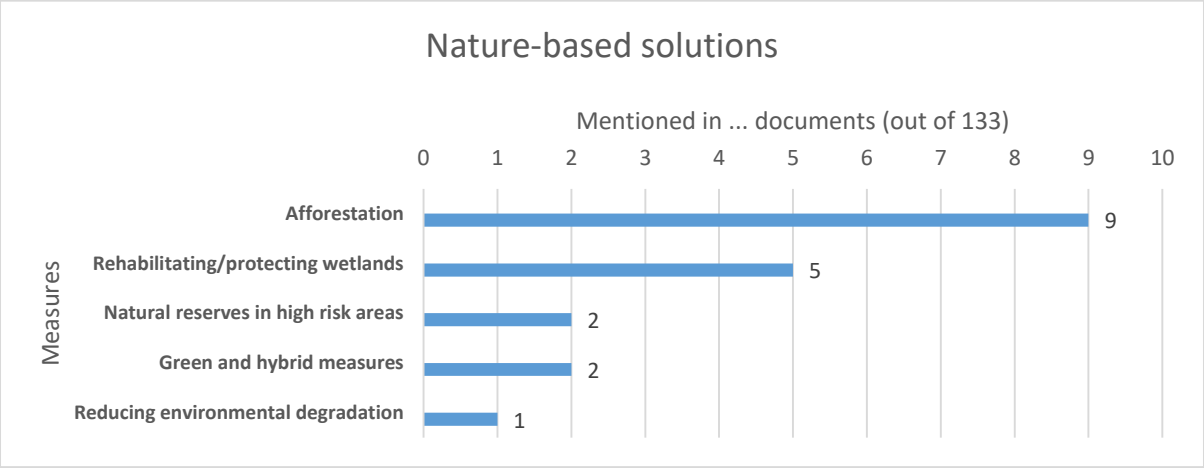
Insurance = *a formalized risk transfer arrangement with an insurance company as the risk carrier*



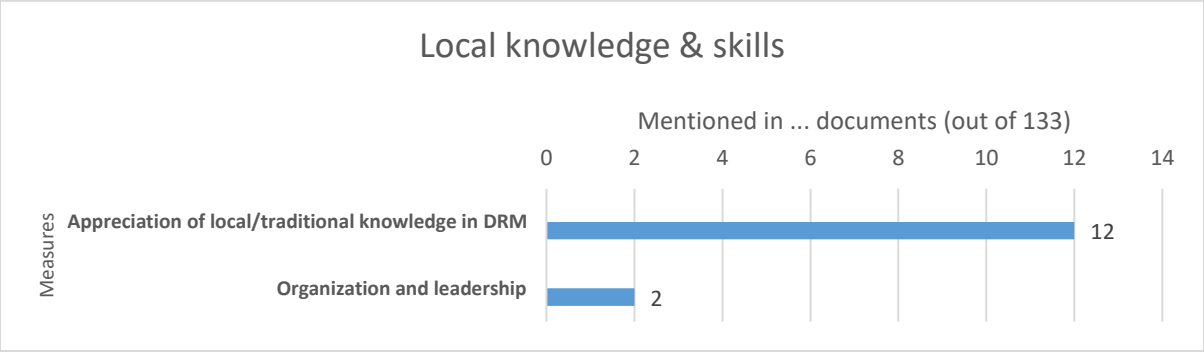
Modification of practices = *the modification of previously applied practices to reduce flood risk or to alleviate the adverse impacts of a flood event*



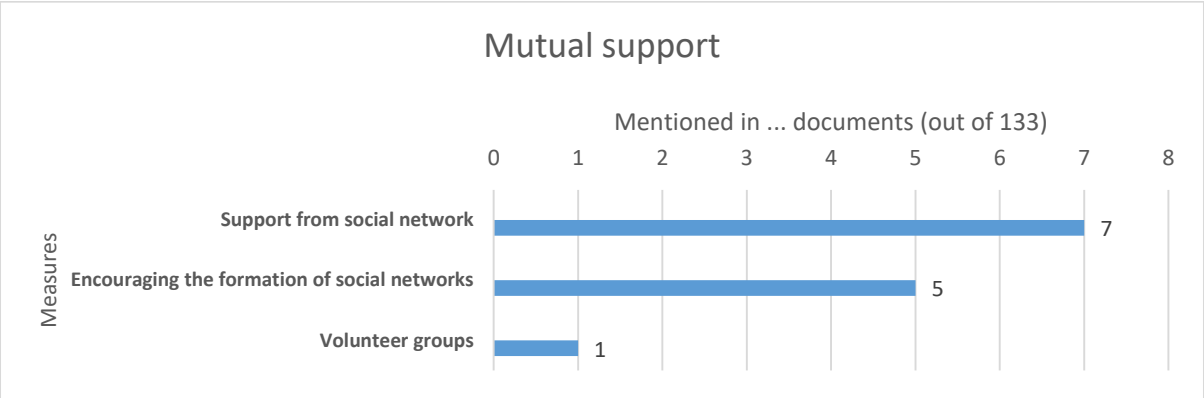
Nature-based solutions = *the use of ecosystem services to reduce flood risk or to alleviate the adverse impacts of a flood event*



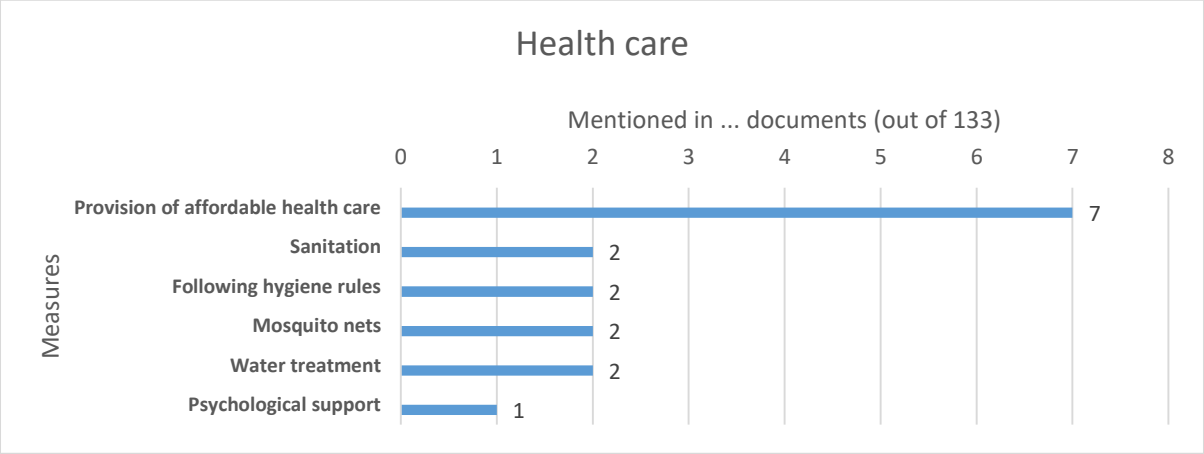
Local knowledge & skills = *the explicit consideration of place-specific knowledge of risk, possibilities to reduce it and to overcome its adverse effects*



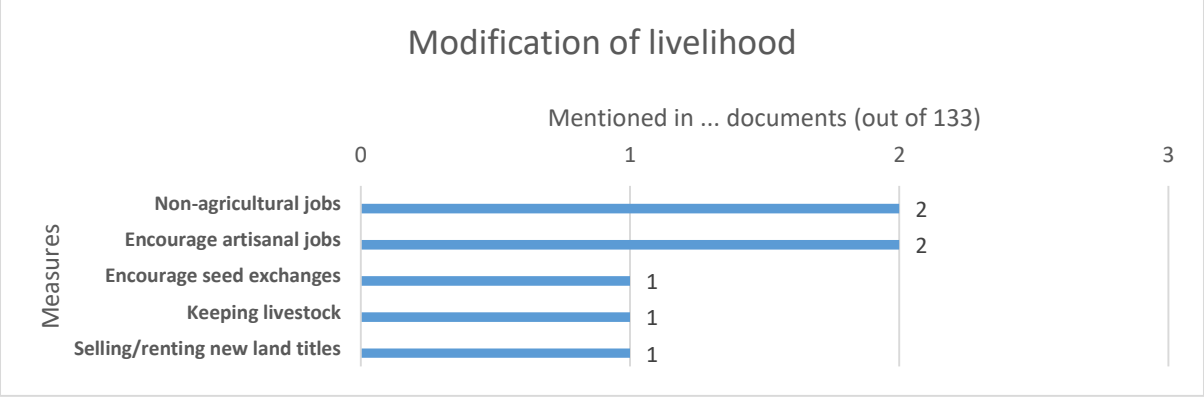
Mutual support = *all measures that summarize mutual support to reduce the risk of and overcome the adverse impacts of floods between people based on solidarity*



Health care = *the use of health care to reduce flood risk or to alleviate the adverse impacts of a flood event*

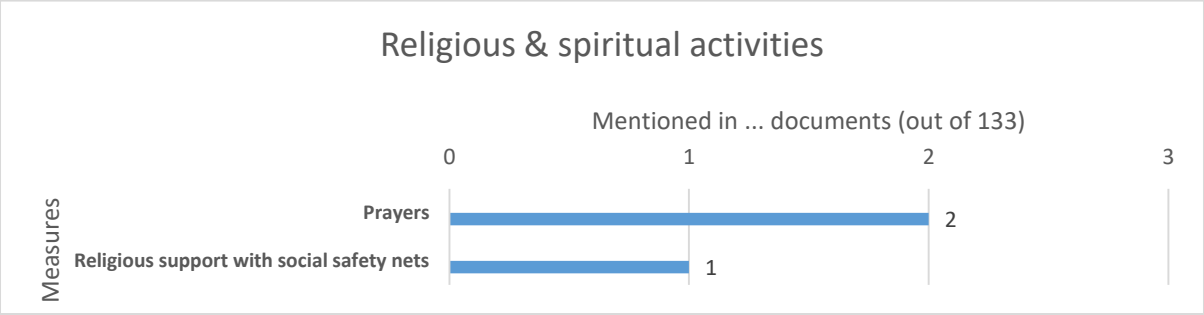


Modification of livelihood = *the modification of previously practiced livelihoods to reduce flood risk or to alleviate the adverse impacts of a flood event*



Risk retention = *retaining of resources to alleviate the adverse effects of unaddressed risk in case of flood event*

Religious & spiritual activities = *the use of religious or spiritual activities to perceive flood risk or to alleviate the adverse impacts of a flood event*



7.2 Annex for "Recovering from Financial Implications of Flood Impacts—The Role of Risk Transfer in the West African Context"

Annex 12 Descriptive statistics for the main input variables of the GLM

Components of *Financial recovery time of a household (all impact types, dependent variable)*

Financial recovery time of a household from agricultural impacts (on average over the past 20 years)

		Freq.	Percent	Cum.
0	No agricultural impacts	32	4.30	4.30
1	Up to 5 months	207	27.82	32.12
2	6 months - 11 months	276	37.10	69.22
3	1 - 2 years	86	11.56	80.78
4	> 2 years	5	0.67	81.45
5	Usually no recovery	138	18.55	100.00
	Total	744	100.00	

Financial recovery time of a household from material impacts (on average over the past 20 years)

		Freq.	Percent	Cum.
0	No material impacts	246	33.06	33.06
1	Up to 5 months	156	20.97	54.03
2	6 months-11 months	182	24.46	78.49
3	1-2 years	79	10.62	89.11
4	> 2 years	11	1.48	90.59
5	Usually no recovery	70	9.41	100.00
	Total	744	100.00	

Financial recovery time of a household from health impacts (on average over the past 20 years)

		Freq.	Percent	Cum.
0	No health impacts	125	16.80	16.80
1	Up to 5 months	235	31.59	48.39
2	6 - 11 months	239	32.12	80.51
3	1 - 2 years	70	9.41	89.92
4	> 2 years	10	1.34	91.26
5	Usually no recovery	65	8.74	100.00
Total		744	100.00	

Financial recovery time of a household from trade impacts (on average over the past 20 years)

		Freq.	Percent	Cum.
0	No trade impacts	201	27.02	27.02
1	Up to 5 months	205	27.55	54.57
2	6 - 11 months	182	24.46	79.03
3	1 - 2 years	74	9.95	88.98
4	> 2 years	9	1.21	90.19
5	Usually no recovery	73	9.81	100.00
	Total	744	100.00	

Components of *Frequency of reoccurrence (all impact types as PCA score)*

Frequency of agricultural impacts (on average over the last 20 years)

	Freq.	Percent	Cum.
0 No agricultural impacts	32	4.30	4.30
1 More than 10 years	1	0.13	4.44
2 Every 5 to 10 years	26	3.49	7.93
3 Every 2 to 4 years	114	15.32	23.25
4 Once a year	419	56.32	79.57
5 Several times a year	152	20.43	100.00
Total	744	100.00	

Frequency of material impacts (on average over the last 20 years)

	Freq.	Percent	Cum.
0 No material impacts	246	33.06	33.06
1 More than 10 years	6	0.81	33.87
2 Every 5 to 10 years	29	3.90	37.77
3 Every 2 to 4 years	90	12.10	49.87
4 Once a year	326	43.82	93.68
5 Several times a year	47	6.32	100.00
Total	744	100.00	

Frequency of health impacts (on average over the last 20 years)

	Freq.	Percent	Cum.
0 No health impacts	125	16.80	16.80
1 More than 10 years	2	0.27	17.07
2 Every 5 to 10 years	23	3.09	20.16
3 Every 2 to 4 years	112	15.05	35.22
4 Once a year	397	53.36	88.58
5 Several times a year	85	11.42	100.00
Total	744	100.00	

Frequency of trade impacts (on average over the last 20 years)

	Freq.	Percent	Cum.
0 No trade impacts	201	27.02	27.02
1 More than 10 years	2	0.27	27.28
2 Every 5 to 10 years	11	1.48	28.76
3 Every 2 to 4 years	109	14.65	43.41
4 Once a year	353	47.45	90.86
5 Several times a year	68	9.14	100.00
Total	744	100.00	

Components of *Severity of reoccurrence (all impact types as PCA score)*

Severity of agricultural impacts (on average over the last 20 years)

	Freq.	Percent	Cum.
1 No agricultural impacts	32	4.30	4.30
2 Weak	27	3.63	7.93
3 Medium	265	35.62	43.55
4 Strong	420	56.45	100.00
Total	744	100.00	

Severity of material impacts (on average over the last 20 years)

	Freq.	Percent	Cum.
1 No material impacts	246	33.06	33.06
2 Weak	31	4.17	37.23
3 Medium	203	27.28	64.52
4 Strong	264	35.48	100.00
Total	744	100.00	

Severity of health impacts (on average over the last 20 years)

	Freq.	Percent	Cum.
1 No health impacts	125	16.80	16.80
2 Weak	36	4.84	21.64
3 Medium	320	43.01	64.65
4 Strong	263	35.35	100.00
Total	744	100.00	

Severity of trade impacts (on average over the last 20 years)

	Freq.	Percent	Cum.
1 No trade impacts	201	27.02	27.02
2 Weak	39	5.24	32.26
3 Medium	285	38.31	70.56
4 Strong	219	29.44	100.00
Total	744	100.00	

Existing financial coping strategies

Cooperatives

		Freq.	Percent	Cum.
0	No	565	75.94	75.94
1	Yes	179	24.06	100.00
	Total	744	100.00	

NGO support

		Freq.	Percent	Cum.
0	No	537	72.18	72.18
1	Yes	207	27.82	100.00
	Total	744	100.00	

Insurance

		Freq.	Percent	Cum.
0	No	720	96.77	96.77
1	Yes	24	3.23	100.00
	Total	744	100.00	

Credits (from a bank)

		Freq.	Percent	Cum.
0	No	722	97.04	97.04
1	Yes	22	2.96	100.00
	Total	744	100.00	

Dealing with own resources

		Freq.	Percent	Cum.
0	No	399	53.63	53.63
1	Yes	345	46.37	100.00
	Total	744	100.00	

Governmental support

		Freq.	Percent	Cum.
0	No	485	65.19	65.19
1	Yes	259	34.81	100.00

	Total	744	100.00	100.00

Community solidarity funds

		Freq.	Percent	Cum.
0	No	648	87.10	87.10
1	Yes	96	12.90	100.00
	Total	744	100.00	

Credits (from savings groups)

		Freq.	Percent	Cum.
0	No	572	76.88	76.88
1	Yes	172	23.12	100.00
	Total	744	100.00	

Credits (from a private lender)

		Freq.	Percent	Cum.
0	No	705	94.76	94.76
1	Yes	39	5.24	100.00
	Total	744	100.00	

Remittances (family & friends)

		Freq.	Percent	Cum.
0	No	646	86.83	86.83
1	Yes	98	13.17	100.00
	Total	744	100.00	

None of mentioned options

		Freq.	Percent	Cum.
0	No	653	87.77	87.77
1	Yes	91	12.23	100.00
	Total	744	100.00	

Financial recovery time

Components:

Financial recovery time from agricultural impacts (average last 20 years)

Financial recovery time from material impacts (average last 20 years)

Financial recovery time from health impacts (average last 20 years)

Financial recovery time from trade impacts (average last 20 years)

Principal components/correlation Number of obs = 744

Number of comp. = 1

Trace = 4

Rotation: (unrotated = principal) Rho = 0.5817

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.32672	1.67018	0.5817	0.5817
Comp2	.656544	.112475	0.1641	0.7458
Comp3	.544069	.0714013	0.1360	0.8818
Comp4	.472667	.	0.1182	1.0000

The score (component 1) explains ~58% of the total variance of all for variables.

Principal components (eigenvectors)

Variable	Comp1	Unexplained
__5_18_9 Financial recovery time from agricultural impacts	0.5041	.4088
__5_19_10 Financial recovery time from material impacts	0.4705	.4849
__5_20_9 Financial recovery time from health impacts	0.5294	.3479
__5_21_9 Financial recovery time from trade impacts	0.4942	.4317

The score (component 1) is most correlated to __5_20_9 (~53%)

Frequency of flood impacts with financial implications

Components:

Frequency of agricultural impacts (average last 20 years)

Frequency of material impacts (average last 20 years)

Frequency of health impacts (average last 20 years)

Frequency of trade impacts (average last 20 years)

Principal components/correlation Number of obs = 744

Number of comp. = 1

Trace = 4

Rotation: (unrotated = principal) Rho = 0.4764

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.90574	1.07971	0.4764	0.4764
Comp2	.826028	.16507	0.2065	0.6829
Comp3	.660958	.0536845	0.1652	0.8482
Comp4	.607273	.	0.1518	1.0000

The score (component 1) explains ~48% of the total variance of all for variables

Principal components (eigenvectors)

Variable	Comp1	Unexplained
__5_18_2_ Frequency of agricultural impacts (average last 20 years)	0.4394	.6321
__5_19_2_ Frequency of material impacts (average last 20 years)	0.5263	.472
__5_20_2_ Frequency of health impacts (average last 20 years)	0.5488	.426
__5_21_2_ Frequency of trade impacts (average last 20 years)	0.4782	.5641

The score (component 1) is most correlated to __5_20_2 (~55%)

Severity of flood impacts with financial implications

Components:

Severity of agricultural impacts (average last 20 years)

Severity of material impacts (average last 20 years)

Severity of health impacts (average last 20 years)

Severity of trade impacts (average last 20 years)

Principal components/correlation Number of obs = 744

Number of comp. = 1

Trace = 4

Rotation: (unrotated = principal) Rho = 0.5303

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.12103	1.38286	0.5303	0.5303
Comp2	.738162	.123358	0.1845	0.7148
Comp3	.614804	.0887981	0.1537	0.8685
Comp4	.526006	.	0.1315	1.0000

The score (component 1) explains ~53% of the total variance of all for variables

Principal components (eigenvectors)

Variable	Comp1	Unexplained
__5_18_3_ Severity of agricultural impacts (average last 20 years)	0.4481	.5741
__5_19_3_ Severity of material impacts (average last 20 years)	0.5203	.4258
__5_20_3_ Severity of health impacts (average last 20 years)	0.5414	.3783
__5_21_3_ Severity of trade impacts (average last 20 years)	0.4852	.5008

The score (component 1) is most correlated to __5_20_3 (~54%)

Annex 14 Separate GLM for the relationship between the frequency of impacts and the remaining independent variables

Survey: Linear regression

Number of strata = 24	Number of obs = 724
Number of PSUs = 724	Population size = 6,920.6052
	Design df = 700
	F(14, 687) = 4.56
	Prob > F = 0.0000
	R-squared = 0.0762

Frequency (all flood impacts types)	Linearized Coefficient	std. err.	P>|t|	[95% conf.	interval]
HH Income per year	-.072381	.0371164	0.052	-.1452537	.0004918
Residence Country: Togo	-.121166	.0697034	0.083	-.2580187	.0156868
Level of HH's agricultural dependency	-.0819728	.0422101	0.053	-.1648463	.0009008
Cooperatives	-.1978956	.0902278	0.029***	-.3750451	-.020746
NGO support	.3336607	.090262	0.000***	.1564441	.5108774
Insurance	-.4763062	.2395679	0.047***	-.946664	-.0059484
Credits (from a bank)	.3442748	.160427	0.032***	.029299	.6592506
Dealing with my own resources	-.1964428	.0686071	0.004***	-.3311431	-.0617424
Governmental Support	.0636618	.0873272	0.466	-.1077928	.2351165
Community Solidarity Funds	.1106408	.1199386	0.357	-.1248417	.3461232
Credits (from savings groups)	.1577745	.0830105	0.058	-.0052049	.3207539
Credits (from a private lendor)	.230754	.1309409	0.078	-.0263299	.4878379
Remittances (from friend or family)	-.0853923	.0961479	0.375	-.2741651	.1033805
None of mentioned options	-.1790476	.1281376	0.163	-.4306277	.0725325

*** = significance level p < 0.05

Separate GLM for the relationship between the severity of impacts and the remaining independent variables

Survey: Linear regression

Number of strata = 24	Number of obs = 724
Number of PSUs = 724	Population size = 6,920.6052
	Design df = 700
	F(14, 687) = 12.77
	Prob > F = 0.0000
	R-squared = 0.1649

Severity (all flood impacts types)	Linearized Coefficient	std. err.	P>|t|	[95% conf.	interval]
HH income per year	-.1378533	.0366696	0.000***	-.2098488	-.0658578
Residence Country: Togo	-.4947154	.0676398	0.000***	-.6275166	-.3619141
Level of HH's agricultural dependency	.0328742	.0443661	0.459	-.0542322	.1199807
Cooperatives	-.2048971	.0864626	0.018***	-.3746542	-.03514
NGO support	.3056924	.0898062	0.001***	.1293707	.4820141
Insurance	-.4568194	.2257194	0.043***	-.8999875	-.0136513
Credits (from a bank)	.1106194	.1693635	0.514	-.221902	.4431408
Dealing with my own resources	-.0725752	.0700048	0.300	-.2100197	.0648694
Governmental Support	.1532526	.0839662	0.068	-.0116031	.3181083
Community Solidarity Funds	.3876253	.1221494	0.002***	.1478023	.6274483
Credits (from savings groups)	.2167814	.0820887	0.008***	.0556118	.377951
Credits (from a private lendor)	.2754012	.1513024	0.069	-.0216596	.572462
Remittances (from friend or family)	.017503	.1042907	0.867	-.1872571	.2222631
None of mentioned options	-.3151176	.1234457	0.011***	-.5574859	-.0727494

*** = significance level p < 0.05

7.3 Annex for "What influences the demand for a potential flood insurance product in an area with low previous exposure to insurance? – a case study in the West African Lower Mono River Basin (LMRB)"

Annex 15 Detailed overview of the results

Deep learning	Number of epochs	Country	Loss	Accuracy	Precision	F1_score	Recall
Sequential Neural Network first model	100	All	$5.67x10^{-5}$	1	0.9892	0.9831	0.9678
		Benin	$1.27x10^{-4}$	1	0.9921	0.9901	0.9890
		Togo	$8.17x10^{-5}$	1	0.9910	0.9879	0.9764
Sequential Neural Network second model	100	All	0.2329	0.9350	0.9587	0.9510	0.9435
		Benin	0.1614	0.9756	0.9892	0.9638	0.9398
		Togo	0.1291	0.9512	0.9788	0.9710	0.9635

Annex 16 Confusion matrix

Confusion Matrix		precision	recall	f1-score	Support
Labels	Labels numeric				
Indifferent	0	0.93	0.92	0.93	20
Likely	1	0.98	0.97	0.97	140
Unlikely	2	0.96	0.94	0.95	28
Very Likely	3	0.97	0.97	0.97	53
Very Unlikely	4	0.92	0.91	0.91	5
	micro avg	0.98	0.98	0.97	246
	macro avg	0.95	0.94	0.95	246
	weighted avg	0.97	0.96	0.96	246
	samples avg	0.97	0.97	0.97	246