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PARADeS

MANAGING FLOOD DISASTER RISK IN GHANA

Findings, Products and Recommendations

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Imprint

PARADeS – Participatory assessment of flood-related disaster prevention and development of an adapted coping system in Ghana.

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CONTENTS

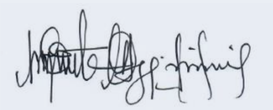
PREFACE

In West Africa, floods and droughts are the major climate hazards that cause disasters. Ghana is highly susceptible to frequent and severe flooding, particularly impacting its urban poor population. In recent years, the country has endured devastating floods, affecting approximately one million people, with the southeastern region witnessing extreme flooding in October 2023, displacing over 26,000 individuals and causing significant damage due to the Akosombo Dam spillage (European Civil Protection and Humanitarian Aid Operations, 2023). Overall, Ghana has faced at least 33 extreme flood events in the past two decades, highlighting the persistent threat posed by flooding in the country. Floods are affecting human lives, impair the economy and damage the environment. The effects of floods are exacerbated when cascading disasters triggered by floods disrupt critical infrastructure, exemplified by the 2015 incident in Accra, where a flood and fire catastrophe led to a gasoline station explosion, claiming 152 lives and causing substantial property damage. Floods and their impacts are expected to become more frequent and extreme in the future. In response, there is a need for research that identifies gaps, challenges and possible interventions in Flood Disaster Risk Management (FDRM) in order to increase Flood resilience in Ghana.

A participatory and transdisciplinary approach is an important prerequisite for improving FDRM as it helps to meet the needs of the FDRM authorities in Ghana and identify ways for sustainable implementation while including local and regional knowledge of experts and citizens from the start. Additional to increasing technical knowledge on flood hazards and impact of changing climate and land use patterns it is of special importance to generate knowledge on possible cascading risks triggered by floods. Of utmost importance is as well to analyse possible flood adaptation measures on the catchment and on the household scale and to provide tools for communication and implementation. Effective governance is key to FDRM that is context specific and characterized by a high degree of complexity both in its institutional settings as well as its policy and stakeholder networks. Thus, collaborative governance is regarded as a key mechanism to improve FDRM. The PARADeS project followed an interdisciplinary, transdisciplinary and socio-technical approach and worked on and provided insights and products on these topics.







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1. INTRODUCTION

1.1 FLOOD DISASTER RISK AND MANAGEMENT IN GHANA

Mariele Evers

Ghana is one of the countries which are most prone to floods in West Africa [1–3] with devastating effects, especially for the urban poor [4].

In recent years, many parts of Ghana have experienced extreme floods affecting about 1 million people [5, 6]. In October 2023, the south-eastern part of Ghana experienced extreme flood events, leading to the displacement of over 26,000 people, as well as the destruction of homes and critical infrastructure [7]. This was due to the spillage of the Akosombo Dam in the Lower Volta. In addition, many regions in Ghana were affected by floods between March and June 2023, leading to the death of 8 people and the displacement of people in areas such as Accra, Kumasi and the western part of Ghana [8]. In 2018, floods caused by high-intensity rainfall combined with water releases from the Bagre Dam in Burkina Faso affected 100,000 people and destroyed 196 km^2 of farmland [9]. The Floodlist database lists 33 extreme flood events in Ghana during the last 20 years.

Besides the annual occurrence of major floods, Ghana also experiences cascading disasters, triggered by floods, which disrupt critical infrastructure. For example, in 2015, Accra experienced a cascade disaster of floods and fire, driven by both natural and human factors. Due to a cigarette dropped into flood water that had fuel on the surface, a state-owned gasoline station exploded, claiming the lives of 152 people and damaging properties worth millions of dollars [10, 11].

For more information on the flood situation and flood disaster risk management please have a look at some related slides and videos.

Figure 1.1: Urban flooding in Accra, Ghana (©NADMO)

Many countries in Africa, particularly in West Africa, have experienced frequent flood disasters since 2015. Studies on the future of floods in Africa show a likely increase in extreme flood risk in western Africa [12]. It has been estimated that about 12% of the African population will face food insecurity after 2020, with various cascading effects such as increasing levels of poverty, loss of lives, and conflicts [13, 14]. Flood Disaster Risk Management (FDRM) regimes and sustainable adaptation approaches are thus urgently needed.

To tackle this, the Ghanaian government has established several policies to reduce flood impacts, such as the National Water Policy [15] or the Blue Agenda [16], which addresses flooding and its related threats by focusing on public education and the enforcement of building regulations.

Figure 1.2: PARADeS Workshop in Accra 2022 ©PARADeS

Despite the existence of several institutional and non-institutional FDRM programmes [e.g., 17], the recurrence of flood disasters shows that the existing FDRM regimes are not sufficiently effective. This discrepancy has been pointed out in previous studies [e.g., 18–20].

This shows the particular importance of socio-political factors which influence the effective implementation of existing laws and policies for FDRM. Moreover, both city authorities and exposed communities commonly embrace a reactive approach, focused on demolition, forced evictions, seeking temporary refuges, and adopting palliative measures [21–23, 16]. These factors draw attention to the need to find and introduce sustainable solutions to managing flood risk in Ghana.

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1.2 AIMS AND SCOPE OF THE PARADES PROJECT

Mariele Evers

The overall objective of the PARADeS project was to contribute towards enhancing Ghana's national Flood Disaster Risk Management (FDRM) strategy, thus increasing the country's resilience to flooding disasters in a sustainable way.

Based on the gaps, weaknesses, and challenges identified during a pre-project [24], the research and development phase focused on Ghana's national flood disaster risk reduction and management strategy by investigating existing flood risk and institutional settings, governance mechanisms for disaster management, human−water interaction, and the development of possible future scenarios and feasible and sustainable measures.

Three case study areas were identified and chosen in a participatory and flood-risk based process (Fig. 1.3. The three study areas were: The Odaw River Catchment in Accra (with a focus on pluvial and coastal floods), Kumasi (with a focus on pluvial and fluvial floods), and the White Volta Catchment (with a focus on fluvial floods).

Implemented through an innovative socio-technical and participatory approaches and tools, our project combined research, development, and institutional strengthening activities. It integrated diverse information and data sources and developed collaborative scenarios and socio-technical tools in order to support coherent decision-making processes.

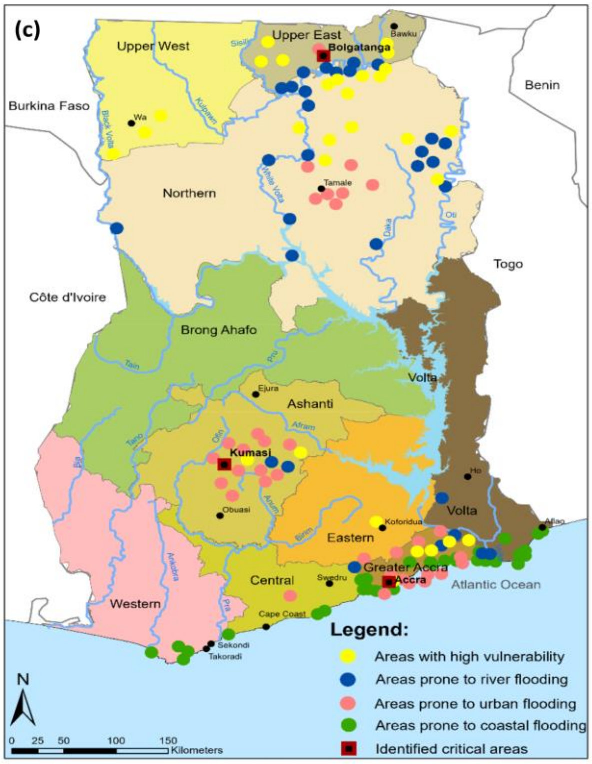

Figure 1.3: Identified study areas in Ghana ©PARADeS

A key aspect was analysing policy and governance setting of flood disaster risk reduction in Ghana, developing different scenarios of flood hazards, investigating and modelling cascading risk effects regarding critical infrastructure, and an assessment tool to identify flood risk at a household level, the FLOODLABEL Ghana. All processes and working steps were realized using interdisciplinary and participatory approaches together with Ghanaian stakeholders (Fig. 1.4). The end products are strengthening institutional and citizens' capacity through a series of activities on societal awareness and training of specialists, decision- and policymakers. Technologically, the project has produced a set of decision support tools (such as the Flood Information System and FLOODLABEL Ghana) to effectively disseminate vital information to citizens, researchers, and decision makers to respond to and mitigate the impact of flooding.

Figure 1.4: Stakeholder Participation ©M. Evers / PARADeS

In sum, to successfully achieve the main objective, the project was composed of a combination of research, development, and institutional strengthening activities. It encompassed social, technical and governance components through intensive stakeholder participation, and socio-technical tools aiming to achieve a sustainable development of FDRM measures.

The consortium partners

Germany:

- University of Bonn (**U-BN**) - Project Coordinator,
- Albert-Ludwigs-University of Freiburg (**U-FB**),
- Flood Competence Center (**HKC**),
- Magdeburg-Stendal University of Applied Sciences (**HS-M**),
- Associate German Partner – Federal Office of Civil Protection and Disaster Assistance (**BBK**).

Ghana:

- Water Resources Commission (**WRC**),
- National Disaster Management Organisation, Ghana (**NADMO**),
- West African Science Service Centre on Climate Change and Adapted Land Use (**WASCAL**),
- Kwame Nkrumah University of Science and Technology (**KNUST**).

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2. THE PARADES APPROACH

2.1 MODELLING THEORY AND APPLICATION

Joshua Ntajal, Roman Schotten, Adrian Almoradie

Hydrological Model

Hydrological models are used to present or simplify the complex interactions and movement of water within the water cycle of a watershed [25]. In general, hydrological models are physically distributed parametric models for simulating the processes and exchanges of water within a water cycle. They provide coordinated guidance for water resource management, river runoff, and flood forecasts, based on return periods of river flow (observed and simulated) under climate change and land use scenarios [25]. Numerous hydrological models exist (e.g., the SWAT model) and have been widely adapted based on the purpose of the modelling and the spatial conditions of the study area [26]. SWAT is a computer simulation hydrological model which uses the water-balance approach to simulate river flow and to predict environmental impacts of land use and climate change. It is suitable for small watersheds and large and data-scarce river basins.

The PARADeS project adopted the SWAT hydrological model, due to its suitability for relatively large and data-scarce catchments, such as the White Volta. In the PARADeS project, the hydrological model focused on the White Volta River catchment that is impacted by floods on an annual basis with devasting effects for households, communities, and critical infrastructure [27]. The White Volta is a transboundary catchment, which is part of the larger Volta River Basin, managed by Ghana and Burkina Faso [28].

The hydrological modelling process in the PARADeS project involved the integration of the SWAT model into Quantum GIS (QGIS) software, as a plugin to delineate watersheds, create hydrological response units, run simulations, and visualise model results. The input data for the SWAT hydrological model for PARADeS broadly included a digital elevation model (DEM), soil data, climate data, and land use and land cover (LULC) data. Additionally, reservoir or dam management parameters for both the Bagre dam and the proposed multipurpose dam at Pwalugu were included as input data for the model. The SWAT-CUP software was used to calibrate the simulated river flow, using the observed daily river discharge data from the Nawuni gauging station, located on the main channel of the White Volta River in Ghana.

The outcome of the hydrological modelling included the generated daily river runoff data and hydrographs, under land use and climate change scenarios. The river runoff data was used to estimate flow return periods as input data for the Flood Information System (FIS).

Hydrodynamic Model

Understanding the impact of floods requires an inter- and transdisciplinary approach supported by flood hazard maps. In this research project, we developed flood hazard maps that made use of a hydrodynamic model to simulate different return periods of extreme flood events.

A hydrodynamic model studies how water moves and the forces that make it move. It uses equations to analyse the physical processes of water flow at different scales and applies the Mannings equation to estimate roughness. This model can focus on different types of floods, like tides, river floods, or rain-induced floods, depending on the features of the area. It comes in different dimensions, such as 1D, 2D, and 3D, but the time and cost factors influence the choice and implementation of the model [29, 30].

The hydrodynamic model that was developed in PARADeS relies on several inputs, including rainfall data (for Accra and Kumasi), discharge data (for the White Volta), a Digital Elevation Model (DEM), cross-sectional data, and land use information used to estimate the Manning's n friction coefficient. The DEM data was derived from DLR TanDEM-X data, cross-sectional data was obtained through a combination of in-situ measurements and LIDAR data (Light detection and ranging), while land use data was sourced from the CORINE Land Use and Cover dataset spanning the years 2015 to 2019.

In PARADeS, the ProMaIDes 1D-2D hydrodynamic model was employed. It was utilised to simulate both fluvial and pluvial flooding for the Accra and Kumasi case studies. For the White Volta region, the model specifically focused on simulating fluvial flooding.

Consequence Models and Risk

Based on the outcome of the hydrodynamic model, the consequences of flooding were derived as well based on models. The translation of inundation maps and water depths to an impact makes it more tangible and allows decision makers to comprehend the flood hazard better. Floods have a multitude of consequences for individuals, mental health, ecology, economy, infrastructure, and so on. In the course of this project, three types of consequences were modelled. PROMAIDES was used to derive the flood consequences for economic damages, consequences for population, and the disruption of critical infrastructure services. Economic damages were derived using land cover data, such as the Sentinel-2 10-Meter Land Use/Land Cover or flood-depth damage relations from the European Joint Research Centre. The affected and endangered populations were derived using the Jonkman [31] approach and population density data from the Meta-Data for Good Team. Critical infrastructure disruptions were derived by developing a new methodology to assess flood risk for critical infrastructure [32]. As an input, publicly available infrastructure data were used from OpenStreetMaps, although the data availability and model quality still remain a challenge [33]. Subsequently, the derived consequences were combined with the return periods from the hydrological model and the hydrodynamic model funnelling into the calculation of catchment-wide flood risk [34]. Based on the flood risk, potential measures could then be investigated.

Modelled Scenarios and measures

In this research project, we carefully analysed the measures that can be incorporated into the model to assess their potential impact on reducing flood risk. These are rainwater harvesting, buffer zone and household protection for Accra and Kumasi, and dams and dykes for the White Volta. These measures were tested under different return periods (T2-T1000) and climate scenarios (RCP 4.5 and 8.5).

Land use/land cover (LULC) change detection and future projects

LULC data is important input for the hydrological model, due to its crucial influences on surface runoff, transportation of sediments, and infiltration rate. Areas with dense vegetation cover tend to increase infiltration and reduce runoff and peak discharge of floodwater [25]. Within the PARADeS project, pre-processed and orthorectified Landsat satellite images were obtained from the US Geological Survey and Copernicus Climate Change Service for 1995, 2005, 2015, and 2020. LULC classification was performed using a supervised classification with a maximum likelihood approach. The LULC maps were generated to detect changes in the LULC classes and used for future projections to obtain LULC maps for 2030, 2050, and 2070, using the Markov Chain approach in the Land Change Modeler software [35].

Climate change assessment and development of future scenarios

The climate modelling process under the PARADeS project involved the acquisition and selection of six best-performing global circulation models and downscaling, using accurate observed climate times series data. Climate change modelling was based on the Representative Concentration Pathways (RCPs) scenarios RCP 4.5 and 8.5 [36]. Regarding time frames, the historical (or base-case) assessment considered the time from 1970 – 2010. The future climate change projections were divided into two time frames: 2025 – 2060 and 2061 – 2096 (representing 36-year intervals). The data generated from the climate change modelling was used as input for the hydrological modelling and future river flow estimations.

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2.2 PARTICIPATORY SCENARIO DEVELOPMENT

Sylvia Kruse, Britta Höllermann, Ida Wallin, Mariele Evers

Shared Problems, Desired Futures and Possible Adaptation Pathways.

Scenario development is often recognised as a valuable approach for addressing socio-ecological problems such as flood risks that are characterised by intricate, unpredictable, and uncertain challenges [37]. Applying a participatory methodology when developing future scenarios has been shown to not only integrate different perspectives and mobilise a broad variety of knowledge but also to help facilitate credibility and mutual learning for planning and future response [38]. In PARADeS, the participatory scenario development followed a participatory back-casting approach [39] and focused on the most important factors for the future of Flood Disaster Risk Management (FDRM) in Ghana. This was based on a multi-step process:

1. Identification of causes, impacts and adaptation measures: In a first hybrid workshop series with FDRM stakeholders in 2021, causes, impacts, and adaptation measures were identified using the problem-tree approach. This method helped to jointly carve out the underlying causes of flooding problems in Accra, Kumasi and Bolgatanga and how they relate to land use, urban and rural development, behavioural issues, inadequate drainage systems, and waste management problems. The problems that evolve from these

root causes can lead to impacts, such as the destruction of livelihoods and critical infrastructure, loss of lives and property, limited access to critical infrastructure, reduced human mobility, health problems, and disease outbreaks. Based on the problem tree, participants were able to test which variable (causes and impacts) was targeted by the adaptation measures and how these measures translate through the system. In the first round, it became clear that a combination of hard and soft measures is needed to effectively reduce flood risk; however, many of the suggested measures focused on short-term perspectives. During the second workshop when applying a scenario exercise (see also step 3 of the process) the measures tended to be more transformative and long-term. However, there are distinct differences between urban and rural and between stakeholder and affected population priorities and necessities for adaptation measures (see chapter 3.3).

2. Developing shared understanding of problems and desirable futures in Flood Disaster Risk Management: In the second round of workshops (year 2022) in a face-to-face setting in Accra and Bolgatanga, stakeholders from different fields of practice and expertise discussed the results of the first hybrid workshop series. In this workshop, a common understanding was developed of problems, desirable futures, policy options and adaptation measures in FDRM using a 30 years' time frame. For this, the participating stakeholders were asked what policy options they considered necessary and plausible; they thus developed a policy toolbox addressing different policy levels from local to national and supranational as well as considering different policy instruments from regulatory and financial to informational, educational, and collaborative instruments.

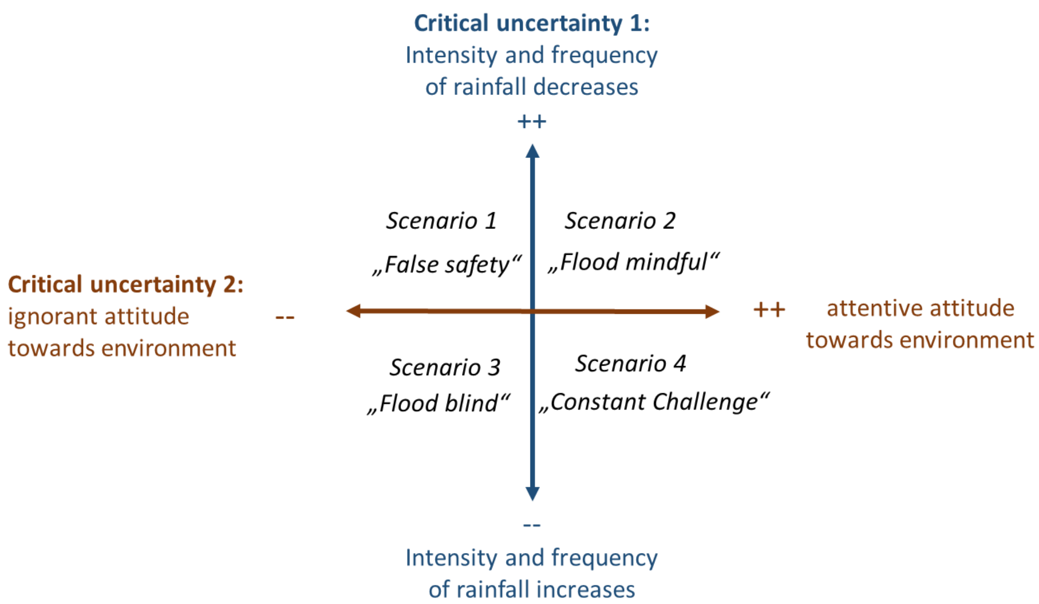

Figure 2.1: 2x2 scenario matrix for explorative scenario development. Scenarios are created by using the two most critical uncertainties and combining them from positive to negative development. Example from Bolgatanga ©B. Höllermann / PARADeS

3. Developing scenarios and robust pathways: Building on the shared problems, the participants formulated a set of different scenarios. The scenarios were built using an impact/uncertainty grid to convey critical uncertainties. Critical uncertainties are those whose impact is assessed as very high and whose uncertainty is also high. In the case of Bolgatanga, high intensity rainfall, human attitude towards the environment and dam burst were identified as critical uncertainties. Two of those uncertainties were commonly chosen to create a 2x2 scenario matrix where both uncertainties cover a range from positive to negative development thereby creating 4 explorative scenarios (Fig. 2.1). In moderated group work (following the world-café method, see OER material "6 Collaborative governance – Stakeholder engagement tools") the participants subsequently discussed the policy and adaptation options of each scenario which could lead to the identified desirable future.

This activity resulted in robust pathways towards improved FRDM taking into account local context (see chapter 3.3). It also strengthened collaboration and trust among the stakeholders.

The participatory scenario development and identification of adaptation measures were also key for the improvement of the hydrological and hydro-dynamic models (e.g. adapted land use planning, wetland protection, and the creation of retention ponds and dams). The scenario analysis was the key element in the Collaborative Modelling approach for practising and applying holistic and integrative thinking (see chapter 3.1).

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2.3 APPLIED INTERDISCIPLINARY RESEARCH: HOW TO CO-CREATE MEANINGFUL RESULTS

Sylvia Kruse, Mariele Evers, Britta Höllermann

In flood disaster risk research, interdisciplinary research has a large potential to improve knowledge and reduce disaster risk, as the complexity and uncertainty of flood risk disasters call for the integration of multidisciplinary knowledge. Nevertheless, this involves some challenges in designing and realising collaborative research processes [40]. To enable cross-pollination between the disciplines, collaborators from more than one academic discipline and expertise need to systematically engage and integrate disciplinary knowledge on the formulation of problems and possible solutions, use of data and the conceptualisation and implementation of methods.

In PARADeS, which addresses the socio, technical and governance components of Ghana's Flood Disaster Risk Management (FDRM), researchers from geography, civil engineering, hydrology, social sciences and environmental governance collaborated closely throughout the research process starting with (1) the analysis of the problems, root-causes and institutional setting, (2) the improvement of the FDRM specific data base and the modelling of flood risk under different climate change scenarios and adaptation options, as well as cascading impact to critical infrastructures, and (3) the development of tailored tools for implementation (e.g. the FLOODLABEL, the flood information system (FIS) or the training on collaborative governance in FDRM).

Besides interdisciplinary research for FDRM, transdisciplinary research is also necessary to co-produce knowledge for meaningful results. Transdisciplinary research includes knowledge from scientific and non-scientific experts, stakeholders as well as citizens, in order to address society-relevant problems, enable mutual learning among participants from various disciplines and actors, and co-create solution-oriented knowledge [41]. Research on sustainability transformation identified three generic mechanisms that create the impact of transdisciplinary co-production of knowledge: first, that it promotes knowledge for more informed and equitable decision-making, second, that it fosters social learning that enables collective action in response to the identified challenges, and third, that it enhances competences for reflective leadership [42].

In PARADeS, the enhancement of knowledge, specifically on flood risk scenarios, adaptation pathways, governance arrangements and institutional settings, was at the centre of interest in the project. The products of PARADeS will enable the planners and managers to make better decisions (target knowledge). These products were the results from the developed hydrological and hydrodynamic models, the integration of critical infrastructure and societal adaptation and response options as well as the analysis of policy networks and institutional vulnerabilities and the specific and situated knowledge for FDRM in Ghana (system knowledge). Social learning and collective action were also core aims of the inter- and transdisciplinary setting.

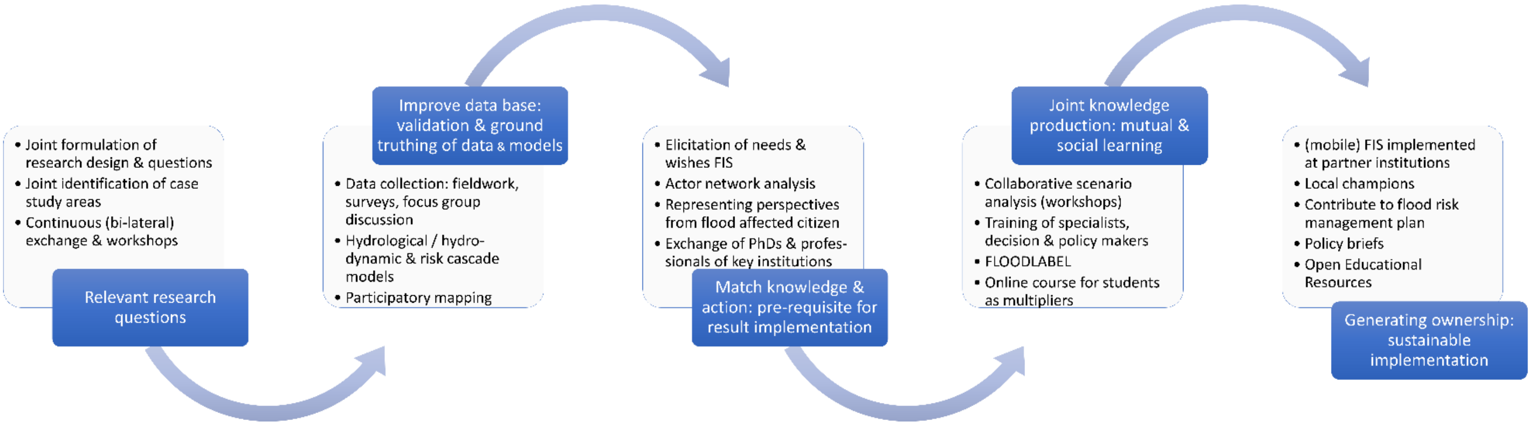

Figure 2.2: The PARADeS Approach as an illustration ©B. Höllermann / PARADeS

This was realised by e.g. participatory stakeholder workshops that were not only used for co-creation of knowledge (e.g. scenario development or adaptation pathways or feedback on the requirements and design of the FIS) but also resulted in a process of building mutual understanding, trust among the participants present, and co-ownership of the products. This is specifically important in FDRM, because to address the root causes of flood disasters, multiple fields of practice and expertise are needed from water resources, housing, flood plain management and community engagement, including authorities on all levels of action from national to local (transformation knowledge). The PARADeS research approach is thus characterised by a collaborative approach from project design to implementation (Fig. 2.2).

Using another approach for the co-creation of knowledge and mutual learning, PARADeS initiated an exchange of high- and mid-level experts and administrative staff of disaster management organizations in Germany and Ghana. The same applies to the academic exchange between universities, which included students, PhDs, as well as mid- and high-level academics. Both helped to intensify collaboration between the respective organisations as well as to foster understanding of the specific perspectives, expertise and situational setting of FDRM in Germany and Ghana.

Further, in order to create outcomes that can be implemented beyond the scope and timeframe of the project, PARADeS aimed early in the development of the project to prepare the transferability and continuation of the outputs. This helped to create both ownership and structure for the sustainable implementation of the FIS in the setting of the newly established Flood Early Warning Centre.

Nevertheless, project-based, inter- and trans-disciplinary research in a German-Ghanaian environment also encounters a number of structural barriers that make cooperation and sustainable implementation of the results more difficult. These include a funding structure that allows only a limited budget transfer between researchers and experts, an inherently short-term project perspective that aggravates long-term personnel commitment, and last but not least, barriers to visas and travel opportunities.

Finally, based on the experiences with inter- and transdisciplinary research within PARADeS, one of the core factors for creating meaningful and sustaining results is the quality of personal relationships between researchers, focal expert partners and stakeholders. Within PARADeS we were able to develop such relationships with local champions as an important basis for building mutual trust, ownership, credibility and sustainability.

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3. RESULTS

3.1 COLLABORATIVE MODELLING

Roman Schotten, Adrian Almoradie, Joshua Ntajal, Mariele Evers

Understanding flood disasters in the context of Ghana is complex due to the intricate interconnections between human and environmental systems driven by various causes and factors. To tackle the intricate nature of floods and associated risks in Ghana, the PARADeS project conducted modelling efforts by incorporating diverse disciplines and considering the interests, perceptions, and local knowledge of stakeholders. The PARADeS modelling approach is both inter- and transdisciplinary, involving stakeholders through interactive participation. This methodology is referred to as collaborative modelling (CM). CM is an interactive and iterative process with continuous engagement of local stakeholders and experts constantly complemented by models (i.e. hydrological and hydrodynamic modelling as well as models for analysing consequences) and communication tools [43, 44]. The following illustrates the interdisciplinary nature of the approach, followed by an exploration of its transdisciplinary aspects.

The analysis of flood risk is in itself already an interdisciplinary effort since a range of academic disciplines are coming together and are complemented by continuous communication and exchange with stakeholders. Figure 3.1 is a graphical representation of the flood risk management process which highlights different aspects of collaborative modelling [45]. The basis of integrated management relies on flood risk analysis to describe current flood risk situations. At the beginning of the flood risk modelling stands the hydrological model analysis which deals with the identification of discharges as well as their associated return periods and subsequently the probability of occurrence. Climate models can be used to change the environment of hydrological boundaries and allow consideration of the effects of climate change on the hydrological domain. Based on the hydrological results, hydrodynamic models were used to outline inundation areas, flood depths, and the temporal dynamics of flood events. The determination of flood risk is based on the findings of hydrodynamic models and the consequences for different aspects of society.

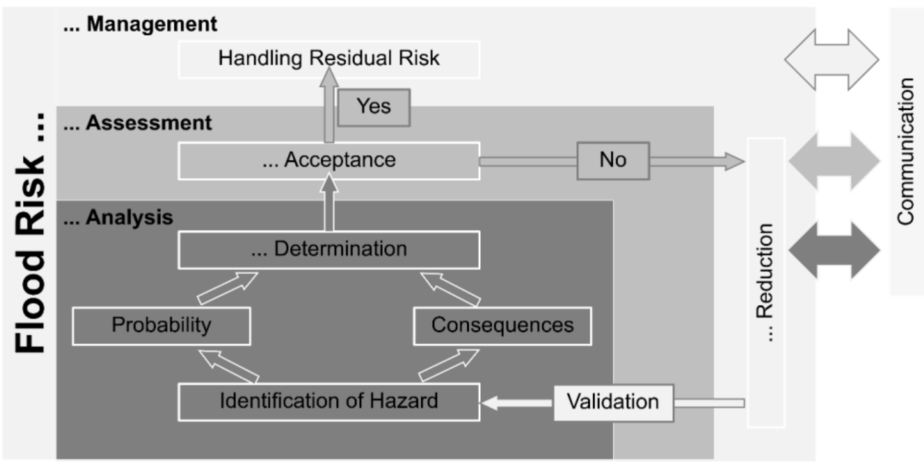

Figure 3.1: Flood risk analysis by modelling in the context of an integrated flood risk management (©PARADeS)

This subsequently requires an understanding of economic values, population characteristics, and the infrastructure system that is exposed. The combination of this exposure, the probability of occurrence, and the characteristics of flooding leads to the modelled flood risk as a multidisciplinary outcome.

In the PARADeS project, the associated consequences of flood risk were assessed using Climate Models, the SWAT hydrological model, and the ProMaIDes hydrodynamic and consequence models.

Climate models and hydrological models – probability and boundary for the identification of hazards.

The hydrological model was established for the White Volta primarily because of the expansive geographical coverage of this region. The model produced discharges that were used as inputs to the hydrodynamic model. Climate models that were used to derive climate change scenarios produced possible futures of temperature and rainfall data. The data were subsequently analysed to determine future rainfall return periods, which were then utilised as inputs for the hydrological and hydrodynamic models in the case study areas.

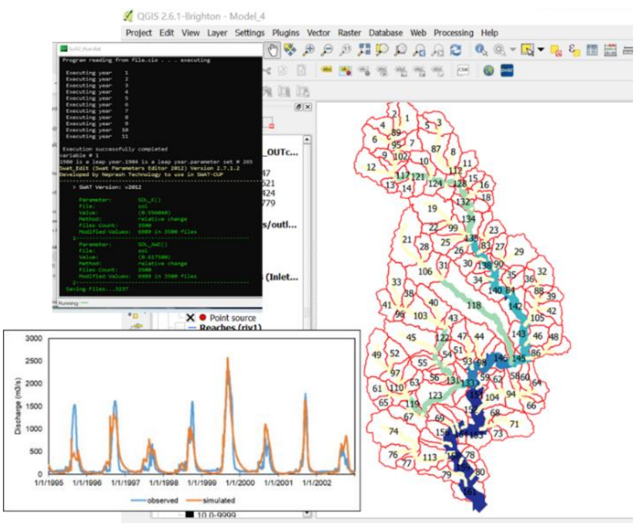

Figure 3.2: Hydrological modelling pre and post processing (White Volta) (©PARADeS)

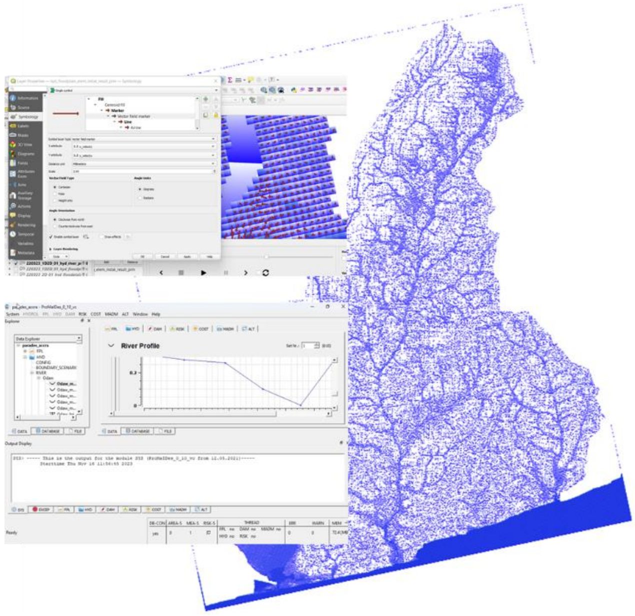

Figure 3.3: Hydrodynamic modelling pre and post processing (Odaw-Accra) (©PARADeS)

Hydrodynamic models deriving flood depths.

The hydrodynamic model produced flood hazard maps for the simulation of various return periods for extreme flood events. In the Odaw-Accra and Aboabo-Kumasi case studies, measured rainfall data and derived future rainfall from the climate model served as input data, whereas the White Volta case study utilised both measured discharge and discharge simulation results from the hydrological model.

Flood Consequence Models.

The consequence model analysed the affected and endangered population (POP) measured in number of people, economic consequences (ECN) in USD, and the consequences for the critical infrastructure disruption (CIN) quantified as disrupted people and days of disruption. The consequences for the population rely on population density data and water-depth/velocity-human interaction values. The critical infrastructure consequences are more complicated to assemble because they do not rely on spatial 2D datasets but rather on a network which includes CI components as well as their flood-interaction and service-related characteristics.

Continuous Communication – Transdisciplinary CM.

Communication with stakeholders was ongoing in all steps of flood risk management, defining an interactive participatory approach driven by a generated common understanding among stakeholders regarding flood risk, and sets of Flood Disaster Risk Management (FDRM) measures were jointly identified and ranked for further consideration in the models that will support the planning and management of floods. The transdisciplinary CM approach of the PARADeS was carried out in three key steps with stakeholder inputs: (1) identification of flood hotspots, (2) identification of hazards and CI cascading disaster scenarios and sets of ranked measures, and (3) validation of the hydrodynamic and CI modelling results.

The identification of flood hotspots through stakeholder participatory mapping indicated the most critical areas in the three case study areas that were subsequently used for the validation discussion of the modelling results in a workshop (Fig. 3.4).

In a workshop session, scenarios and potential adaptation measures were gathered and deliberated upon with input from all stakeholders. Subsequently, the collected measures were ranked or selected according to their implementation preferences (Fig. 3.5). Objectively useful modelling can help in decision making to determine whether measures should be considered and implemented. Therefore, the models provide a basis to prove the effectiveness of flood measures based on this input.

Dissemination of the CM results.

The spatially explicit products derived from these models are made available through the developed Ghana-Flood Information System (FIS). Users can access flood hazard and consequence maps for different return periods (T2 to T1000), scenarios of climate, and some measures if implemented.

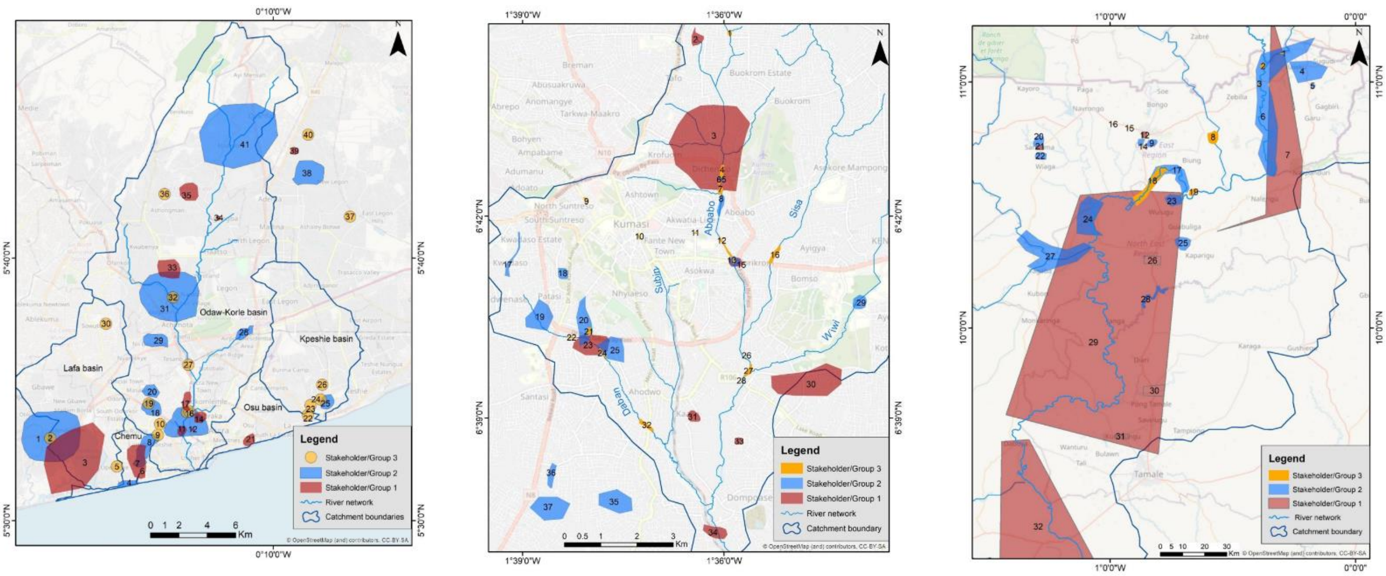

Figure 3.4: Stakeholder mapping of flood hotspots from left to right - Odaw-Accra, Aboabo-Kumasi and White Volta (©PARADeS)

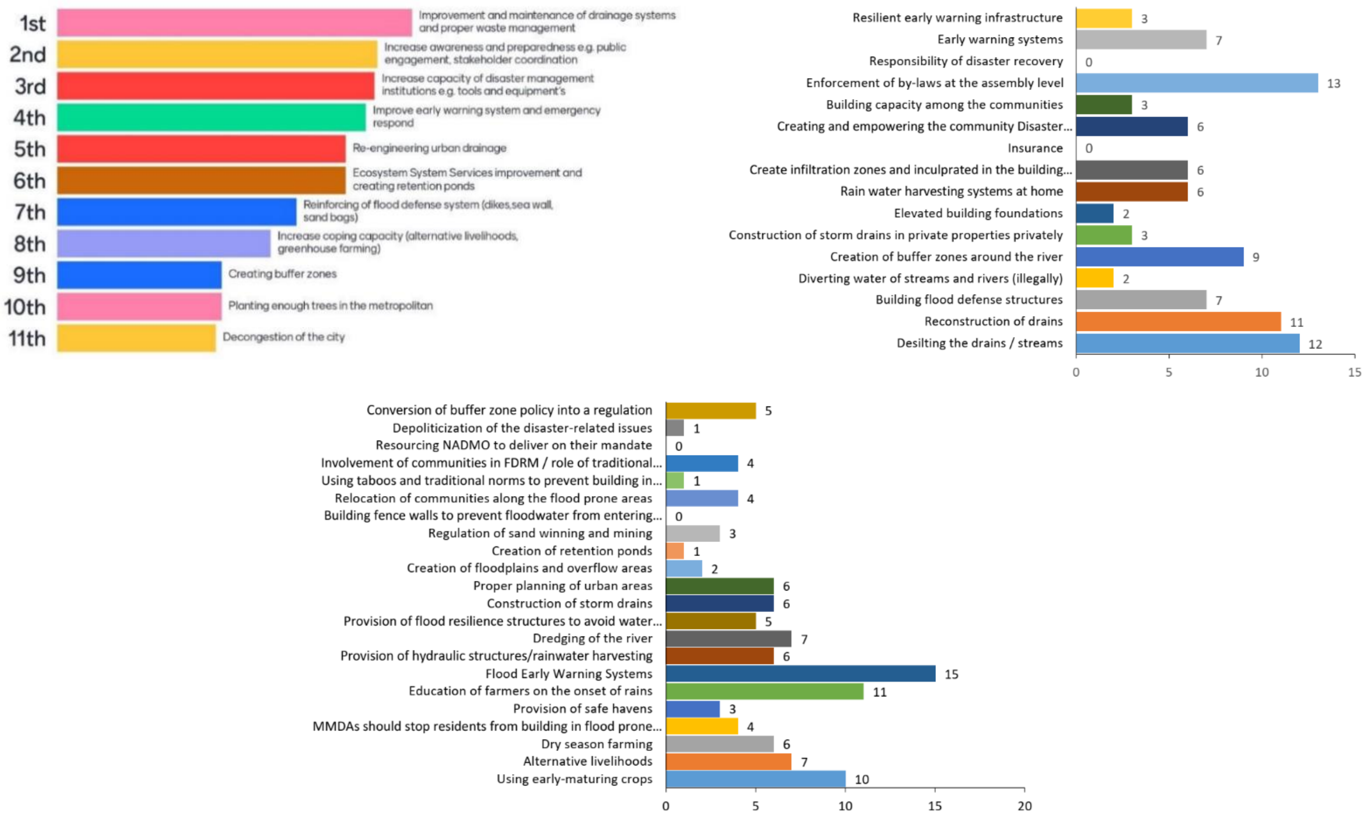

Figure 3.5: Stakeholder ranking of measures: Odaw-Accra (top-left), Aboabo-Kumasi (top-right) and the White Volta (bottom) (©PARADeS)

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3.2 FLOOD INFORMATION SYSTEM (FIS)

Adrian Almoradie

The Ghana-FIS, developed for the catchments Odaw (Accra), Aboabo (Kumasi) and the White Volta, is a web-based application to support and improve decision-making capabilities for Flood Disaster Risk Management (FDRM) by bringing together scientific data and local knowledge produced by the models and inputs from stakeholders. Stakeholder inputs were obtained from two stakeholder workshops (Fig. 3.6), engaging them on the validation of hazard results and the requirements, needs and design of the FIS. At its current stage, it serves for now as an informational tool for the case study areas and later will be used for operational application. The potential for its operational use will be achieved when it is transferred to the intended Flood Early System in Accra.

Figure 3.6: Stakeholder engagement on the development of the FIS ©PARADeS

The FIS comprises three key elements: the knowledge database, the software, and a user interface that employs open-source software to simplify long-term maintenance, extending its usability beyond the project's duration. Further, the FIS consists of three main sections: The Flood Portal, Data Access, and the FLOODLABEL. In the **Flood Portal** section, users can access spatial information on flood hazard model outcomes, encompassing data on depth, velocity, and their consequences for the population and property damage. Additionally, the map highlights the geographical placement of critical infrastructure (CI) and safe havens, as well as the specific locations designated for hydraulic scenarios and mitigation measures. Users will be able to make more detailed selections and have the option to choose the return periods (T2 to T1000), scenarios of current and future climate (climate change scenarios - RCP 4.5 and 8.5), measures - if they have been implemented - and the type of product to present in the map. Users can select their preferred flood information product and proceed to "Send a Request." The section **Data Access** provides users with meta-data information, access to download “Hydro-meteorological data” and “Spatial data” and the software tools to gain access to the data that were used in this research project. The provided hydro-meteorological data includes rainfall, discharge, temperature, and tides collected in this research study. The data is made available to download on request and is accessible using the HEC-DSSVue software. Users can download spatial data such as catchment boundaries, critical infrastructure, modelled flood depths, as well as velocity and other spatial data using the GeoServer Web Service. The **FLOODLABEL** section presents the concept and a concise explanation of how it can be utilized for property assessment and the recommendation of appropriate measures. Furthermore, we offer a brief video and downloadable resources, including flyers, a booklet of measures, and emergency response plans.

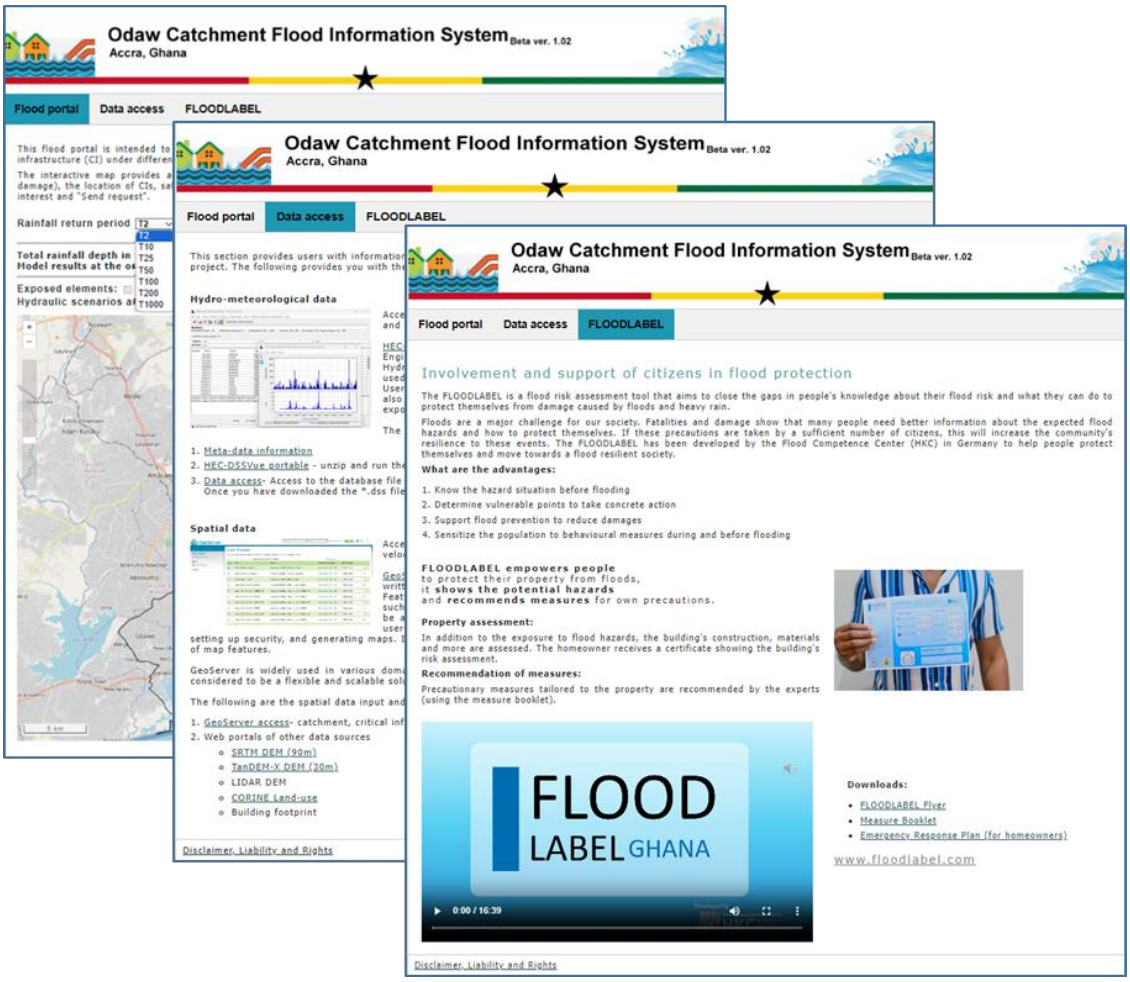

Figure 3.7: **Flood Information System Portal** **©PARADeS**

3.3 ADAPTATION TO FLOOD RISK: CROSS SCALE AND STAKEHOLDER PERSPECTIVE

Britta Höllermann

In Ghana, urban as well as rural areas are prone to flooding [46] and due to climate change an increase in intensity and frequency of potential harmful precipitation events is expected with high confidence [47]. The challenges which the rural and urban residents face differ, where inadequate drainage systems and pressure on land for building houses and businesses dominate in urban areas, it is the pressure on farmland, deforestation and erosion for the rural population [48]. Even though policies and institutional Flood Disaster Risk Management (FDRM) measures have been established to reduce flood impacts [49] currently, reactive rather than preventive approaches dominate [50].

What different groups of stakeholders, such as residents, local government representatives, national disaster managers and hydro-meteorological experts, to name but a few, choose as preferred adaptation measures highly depends on their flood perception, experience and the degree to which they are affected. Insights from PARADeS experts and decision-maker workshops as well as focus group discussions involving locally affected communities in urban and rural settings could highlight commonalities and differences.

While the development of infrastructure (hard) measures to reduce flood risk dominated during the first workshop series in the metropolitan areas of Accra and Kumasi (49% in Kumasi & 1st rank in Accra), this had hardly any relevance during the second workshop where the participants applied a scenario exercise. It can be argued that the scenario perspective opened up the participants' minds to more transformative measures, meaning that flood early warning systems (FEWS) and building structure are important for quick reactions, but only as an add-on, because such measures will not solve the flood risk problem in the long run. In contrast, measures such as land use planning, especially effective wetland management, and enforcement of laws and regulations in combination with efforts to improve education and awareness promise to reduce flood impact in the long term (more details in Fig. 3.8).

For the rural experts and decision-makers, flood defence and water harvesting structures still play an important role since farming activities highly depend on water, and water is thus not only regarded as a risk, but also as a resource. The scenario building exercise revealed that the participants independently developed a step-by-step transformative approach. In scenarios where awareness and attitude towards the environment were low, law and regulation as well as education and awareness are emphasized as priority measures. However, in scenarios where an attentive attitude and behaviour towards the environment is already established, flood protection measures and event management are prioritized. This is in line with the overall learning outcome of the first workshop series, where representatives from the National Disaster Management Organization (NADMO) summarized that hard measures are only effective in combination with soft measures.

Zooming-in to local affected communities revealed a slightly different and less future-oriented perspective, since the residents have to deal with the excess water and have few means of reducing their flood risk. The urban residents stress technical measures and demand governmental efforts to increase and maintain drainage infrastructure, as well as flood defence measures. They also want to become involved in planning such measures to include their local experience. In the rural context, flooding was experienced as one of many other challenges and before effective flood reduction measures can be introduced, more general livelihood support is needed to increase adaptation capacity and resilience.

To avoid mal-adaptation, a shift from project-focused to transformative measures is needed. However, a mixture of long- and short-term measures is still needed to address the acute needs of affected citizens. This is a prerequisite for getting them on board in participatory processes since the expectations of the affected residents and those of decision-makers do not (yet) align. In some parts this means that efforts need to go beyond the water sector to create flood resilience. As the local case study in Northern Ghana highlights, livelihood support is needed first. Also, the urban case studies show that when a reduction of pressure on land and a reactivation of wetlands is envisaged, other livelihood options need to be strengthened. As concluded at the end of the second workshop series, it is important to “appreciate that flood risk management is an integrated task”.

	URBAN Areas	***RURAL Areas***
Experts & Decision-makers	- **Law enforcement = prosecution, sanctions, …** - Community engagement, awareness & **education** - Effective wetland management - Media debates/campaigns - Dedicated budget - Housing programs, strengthening rural livelihoods → **Soft measures**	- **Law enforcement = punishment, no building, …** - **Empowerment of locals**, traditional leaders - Reforestation, agroforestry, maintenance of wetlands - Water harvesting, flood defence structures, dams - Monitoring & early warning systems - Dedicated budget → **Soft & Hard measures**
Local affected communities	- Drainage infrastructure and maintenance of it - **Flood protection** - **Participation** (share experience, get heard) - Early warning dissemination improvement - No disaster relief → **Technical measures**	- Adapted cropping pattern, Agroforestry - **Recession cropping** - Early warning but “What to do?” - No disaster relief - Health care centre → **Livelihood support**

Figure 3.8: Comparison of different perspectives on adaptation measure needs ©B. Höllermann / PARADeS

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3.4 COLLABORATIVE GOVERNANCE AND FLOOD DISASTER RISK MANAGEMENT POLICY NETWORKS

Fafali Roy Ziga-Abortta, Sylvia Kruse

Collaborative governance and networks are essential to excellent Flood Disaster Risk Management (FDRM). While FDRM aims to prevent damage and loss of property, assets, and life caused by floods and related disasters, this goal is often unattainable if stakeholders are not engaged, and procedures, networks, and expertise are unclear in order to carry out coordinated and effective efforts.

Scholars advocate collaborative governance, i.e. public policy decision-making that engages stakeholders within and across governmental bodies, public agencies and non-governmental actors together with local populations to foster increased acceptance and legitimacy of policy interventions [51]. When this happens, policy decisions and outcomes are more likely to be implemented with minimal unnecessary blockage. Collaborative governance and policy networks are, therefore, core to FDRM.

Key factors for collaborative governance in FDRM

Collaborative governance efforts need to be well-considered and coordinated. The key factors that facilitate successful collaboration governance are (1) shared ideas and goals, (2) collaboration and coordination, (3) participation and inclusivity, (4) trading information and communicating, and (5) flexibility and adaptivity (see more in OER training on collaborative governance).

FDRM Policy Implementation Networks in Ghana

In the context of FDRM, policy networks imply a collaborative network of actors working around the subject and the many ties that ensue between them [52]. Policy implementation networks (PINs) carry out the combination of FDRM activities.

In the context of Ghana's FDRM, our research empirically assessed the quality of different network resources such as the type of contact, the level of trust and shared ideas on problem definitions and preferred solutions, and their impacts on the PINs.

Insights based on network characteristics

First, Ghana's FDRM comprise a diversified mix of state agencies anchored by the state's disaster risk reduction (DRR) responsibility [53]. The network focuses on "information and knowledge sharing". However, the current low-density structure of the network projects a lack of adaptability. Such a network thus requires the formation of more connections with each other (i.e., the concept of closure).

This supports the "risk hypothesis" of Berardo & Scholz (2010) [54] that network closure solves cooperation problems. Both centrally powerful and non-central network members reported missing community groups and other skilled experts with innovative ideas. Certain groups may be absent from policy networks due to marginalisation [55] or to strategic decisions by central coordinators to conserve network resources for redundant transitive relationships.

Resource exchange interdependencies in Ghana's FDRM network are intriguing. The complex actor interactions create a competitive interdependent setting. Designated disaster management organisations compete with certain ministries for funding to prevent, mitigate or recover from floods. This causes bickering conflicts with bureaucratic inter-organisational delays among network actors. Clearly, Ghana's FDRM network must decide which actor to invite to work on projects led by another actor. In worst-case scenarios, the network lacks key stakeholders on projects. Representation imbalances hinder collaboration and deliberation [56].

Figure 3.9: PARADeS workshop in Ghana ©G. Johann / PARADeS

Insights based on shared Ideas

The shared ideas in Ghana's FDRM network resemble policy network analysis performed elsewhere [57]. Our research project found five co-existing, mutually non-exclusive networks that cluster on similar problem definitions and preferred solutions, divergent preferred solutions, or vice versa. Based on the theory that exchange processes in PINs require a clear understanding of material and ideational elements, multiple actor clusters interact and collaborate. Note that these networks exist simultaneously and influence policy in different ways based on strategy preferences or shared resources. For instance, while a cluster of network members agree that FDRM in Ghana faces "planning/coordination challenges", only a subset of them in addition to others from different clusters agree on the preferred solution of "adequate planning/ coordination". For some actor clusters, the preferred solution is "attitudinal transformation" because they believe lifestyle changes could necessitate alterations in planning/coordination issues.

In any case, the power of influential state actors and international actors, their interdependencies, and various roles in networks shape shared ideas. The PARADeS research project cannot predict what will happen to Ghana's FDRM network. However, the study's conceptualisation of the network's current state can be used as a starting point to improve network efficiency. To improve FDRM policy networks, we suggest that the following be considered as key:

Networks thrive on diversity

As networks require the broader engagement of other actors beyond the state, space must be made available for the participation of specific non-state actors and the private sector. Actors such as community groups, religious leaders, civil society, non-governmental organisations (NGOs), technical experts, and private practitioners can significantly complement the role of the state as the primary duty bearer of FDRM.

Networks should not pursue common understandings of problems and solutions

One potential means of enhancing the performance of a network is the utilisation of shared ideas. Shared ideas influence relationships within the network. Actors within an FDRM network can share divergent ideas on problem definitions as well as their preferred solutions to the problems. Leveraging these divergent ideas through policy integration or policy coherence where cross-cutting issues can be collectively aggregated more consistently, is key for an effective network.

Trust is pivotal to effectiveness in networks

Effective networks hinge significantly on trust as a dynamic force that can either fortify or weaken bonds among actors. Close contact between network members, regardless of the frequency of communication, should aim at cultivating strong ties. These strong ties foster collaboration and enhance the exchange of information, knowledge, material resources, and expert opinion. Trust, a cornerstone of effective networks, is nurtured and reinforced through mutual understanding and commitment to overarching common FDRM objectives.

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3.5 INSTITUTIONAL VULNERABILITY IN FLOOD RISK MANAGEMENT

Fafali Roy Ziga-Abortta, Sylvia Kruse

Institutional vulnerability directly impacts Flood Disaster Risk Management (FDRM); hence this research emphasises the need to better understand the institutional context in order to identify resilience-building options [58–60]. In the PARADeS project, we explored how the institutional vulnerability of FDRM can be analysed and what drives the specific institutional context in Ghana [61].

The term institutional vulnerability refers to weaknesses embedded in institutions that reduce the capacity to resist, withstand, cope, or recover from the impact of a hazardous event. For our analysis in Ghana, we adapted the framework of Papathoma-Köhle et al. (2021) [62] which serves as a tool to guide institutional vulnerability assessment. The framework identifies four pillars of institutional vulnerability: ***socio-cultural***, ***socio-political***, ***legislative-regulatory,*** and ***fiscal-economic***. Although interconnected, each pillar is specified by a number of drivers.

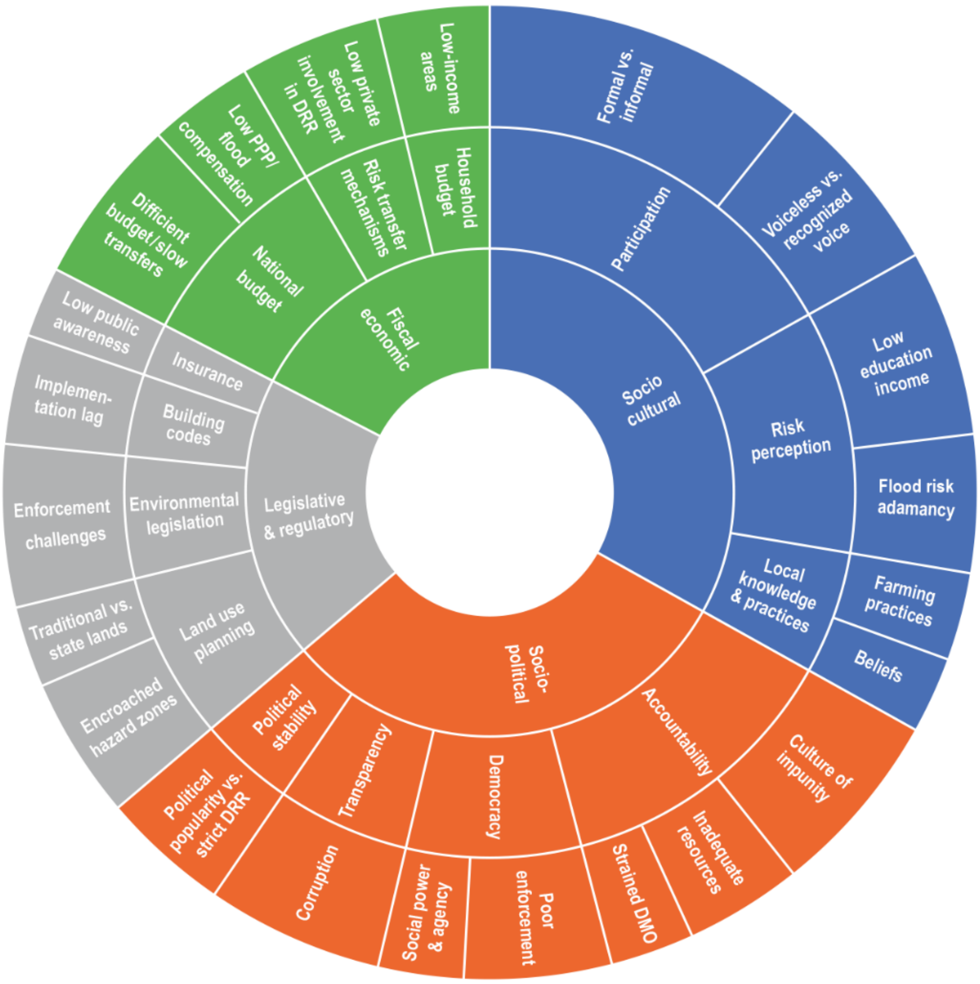

Figure 3.10: Institutional vulnerability drivers in Ghana. The inner circle depicts the 4 pillars of institutional vulnerability. The middle circle represents the possible drivers identified in the literature. The outer circle presents the specific factors identified for FDRM in Ghana [61]. PPP: Public Private Partnership; DRR: Disaster Risk Reduction; DMO: Disaster Management Organization

What drives institutional vulnerability in Ghana?

Socio-cultural drivers: The socio-cultural pillar includes formal and informal rules, the latter being especially important in sub-Saharan African (SSA) contexts, including societal patterns of behaviours, customs, and traditions. The respective drivers are *participation, risk perception, and traditional and local knowledge.*

Socio-political drivers: The socio-political pillar refers to a society's political status related to *accountability, democracy, transparency,* and *political stability*. These four aspects overlap and are intertwined, and countries scoring low on these drivers, including many in SSA, often suffer more deaths from flood hazards.

Legislative and regulatory drivers: The legislative-regulatory pillar encompasses laws and regulations pertaining to FDRM, and can contribute significantly to disaster risk reduction, specifically influencing the capacity of the built environment and society to withstand the impact of flood hazards. The drivers include *land use planning, building codes, environmental legislation,* and *insurance*.

Fiscal economic drivers: The fiscal economic pillar refers to the *household budget* of individuals, to the *national budget* financing of disaster management organisations and to *risk-transfer mechanisms*. The protection of communities from potential flood hazards often depends on national budget and support. However, designated national budgets for disaster reduction are rarely sufficient, reflecting either the incumbent government priorities in other sectors or the low financial status of the country.

How do these drivers foster or hamper Flood Disaster Risk Management in Ghana?

Our analysis identified a set of specific factors of institutional vulnerability drivers (see Figure 3.10; for more details see Ziga-Abortta & Kruse, 2023 [61]). The patterns behind the drivers that hamper or foster FDRM in Ghana can be understood as an interplay of three themes:

Formal and informal institutional drivers

The four pillars of institutional vulnerability in FDRM demonstrate a complex interplay between formal and informal institutional drivers, including formal mandates of governmental agencies and the traditional chieftaincy system. The informal system, intimately linked to the formal system, includes risk awareness, self-help coordination, and informal housing in low-income areas and unauthorised building in mid- to high-income areas. Our study reveals a connection between vulnerability drivers and the uneven allocation of resources, highlighting the association between socio-cultural factors, education and knowledge in influencing flood risk perception as depicted in Figure 3.10. The clash between formally educated elites and local, less educated populations contributes to implementation challenges in the socio-political arena, emphasising the importance of recognizing the tension between formal and informal elements.

Behavioural pitfalls and a culture of impunity

Institutional vulnerability in Ghana is significantly compounded by what we refer to as the "culture of impunity," as seen in the challenges of weak enforcement within the Ghanaian planning system. Similar to findings elsewhere [63], our research project found evidence of the ineffectiveness of formal corruption control systems. Note that the "misrule of laws" generates difficulties in FDRM policy execution, encouraging waste disposal challenges, and encroachment, which eventually impede development within the context.

Deficits in necessary resources and risk transfer mechanisms.

Resource deficiencies in FDRM in Ghana, beyond fiscal limitations, involve socio-cultural and political factors. The lack of accountability undermines transparent duty performance, hindering resource-intensive FDRM phases requiring public participation and skilled expertise. Evidently, insufficient financial resources complicate insurance-based solutions for flood losses, establishing causal links between financial constraints and challenges in effective FDRM risk transfer mechanisms.

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4. INNOVATIONS AND PERSPECTIVES

4.1 FLOOD EARLY WARNING SYSTEM & CENTRE

Mawuli Lumor, Charlotte Norman, Adrian Almoradie, Mariele Evers

The primary conclusions drawn from the PARADeS project underscore the necessity for a robust Flood Early Warning System (FEWS) and improved communication channels to enhance community resilience in the face of floods. While efforts have been made to implement FEWS in certain regions of Ghana, its effectiveness has been hampered by a lack of adequate data, limitations in information derived from models, and challenges related to technology and technical capabilities. Noteworthy to mention is the FEWS for selected communities under the Community Resilience through Early Warning (CREW) Project, spearheaded by NADMO. The current initiative is the establishment of a Flood Early Warning Centre in Accra, Ghana (FEWS-Accra) through a World Bank facility under the Greater Accra Resilient and Integrated Development (GARID) project. FEWS-Accra is being coordinated by the Water Resources Commission (WRC) in collaboration with Ghana Hydrological Authority (Hydro), Ghana Meteorological Agency (GMet) and National Disaster Management Organization (NADMO).

Based on our investigation on the dissemination of near real time flood warnings, GMet and Hydro's forecasts are transmitted to WRC, NADMO and the Media. Then, NADMO transmits the warnings through its regional, district and zonal officers to the affected communities using the local media and community volunteers. Despite the existing framework, there is a need to enhance institutional and technological capacity further, as a considerable number of alerts and immediate responses fail to reach the affected communities.

In reaction to this, the GARID project (2019- 2026), supported by the World Bank and in collaboration with WRC, gave rise to the conception of the FEWS-Accra Centre. The FEWS aims to support planners and decision makers on disaster risk reduction (DRR) on providing timely and accurate warnings to individuals and communities in areas at risk of flooding, allowing them to take preventive measures and mitigate potential damages. The centre achieves this by providing near real-time information and insights into potential future scenarios related to changes in hazards, their consequences, and risks, considering various factors such as climate and land use changes. The FEWS will involve institutions from data collection to forecasting and dissemination. GMet and Hydro will be responsible for the collection, collation and dissemination of climate and hydrological data as well as weather and flood forecasting.

In the interactions between PARADeS and the GARID project, an opportunity was identified for the GARID project to integrate the Ghana - Flood Information System (FIS) into the FEWS. The value of the FIS developed for Odaw-Accra, Aboabo-Kumasi and the White Volta is that it provides spatially explicit information on hazards (depths and velocities) and its consequences to people, properties/economy and critical infrastructure under different scenarios and selected measures. The FIS additionally offers details about the collected data used in the models. Furthermore, the publicly available information regarding FLOODLABEL Ghana offers a comprehensive overview of assessing and mitigating floods at the household level.

The FIS will be integrated into the FEWS-Accra to provide a user-friendly and interactive information platform for decision-makers makers and researchers. The system will serve as a tool for the dissemination of information such as flood inundation maps for different flood depths and return periods, flooding scenarios, near real time water levels at various sections of the watersheds and rainfall conditions by streaming data from the installed automated tele-transmission hydro-meteorological sensors. The system will also serve as a good source of training materials for researchers and academics by providing information on watershed characteristics, Flood Disaster Risk Management (FDRM), climate adaptation and resilience.

With the completion of the design and implementation of FIS under the PARADeS Project, a Memorandum of Understanding (MoU) earmarked to be signed between the content provider University of Bonn and the GARID project represented by the Water Resources Commission (WRC). The University of Bonn will support the setting up and updating of the FIS, capacity building and technical advice to FEWS-Accra. The FEWS overseeing institution through WRC will furnish the essential equipment, facilities, and data needed for the setup and ongoing maintenance of the FIS.

4.2 FLOODLABEL GHANA

Helene Meyer, Georg Johann

Flooding is a serious risk to urban and suburban areas, especially homes, homeowners, and their loved ones; therefore, it is a major challenge for our society [64, 65]. The vulnerability of a community depends on people's adaptation to and preparedness for flood risk [66]. Providing information to homeowners about the expected flood risk and appropriate flood protection measures for buildings provides an opportunity to prevent fatalities and mitigate property damage. Decisions and behaviours before, during, and after an event can increase the resilience of homeowners and society. Moreover, the resilience of a community to these events increases if a sufficient number of citizens take precautionary measures. Self-precautions and implementation of appropriate protection measures for buildings are important aspects of flood risk management.

Figure 4.1: Evaluation work by FLOODLABEL expert ©WRC / PARADeS

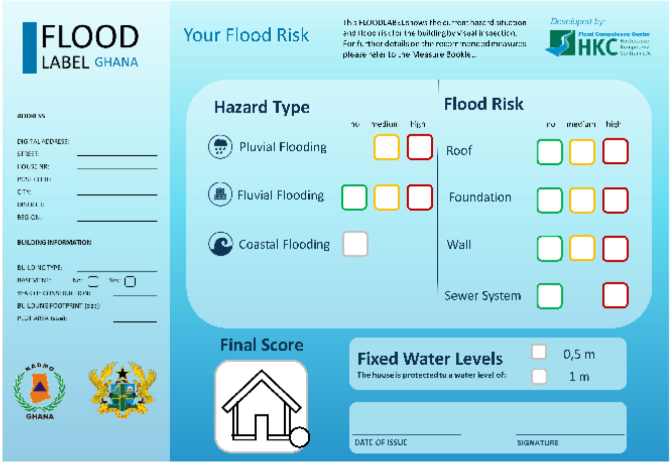

Figure 4.2: FLOODLABEL certificate ©HKC / PARADeS

Involvement and support of citizens in flood protection

Flood risk assessment tools for buildings can help authorities obtain building-specific flood risk information for targeting the implementation of precautionary measures. For Ghana, the Flood Competence Center (HKC) in Germany has developed the FLOODLABEL tool to help homeowners protect themselves and move towards a flood-resilient society. Floods can cause major damage when water enters buildings. Inadequately protected buildings are vulnerable to various types of water inundation. Several measures can be taken to reduce the water inflow and thus the damage. When choosing an appropriate protection measure, efficiency and effectiveness are crucial. The difficulty is that the implementation of these measures is specific to each building. The FLOODLABEL tool makes it possible to assess buildings individually and implement appropriate measures.

Risk reduction

The FLOODLABEL provides a useful instrument as a prevention tool showing ways of taking suitable action before a flood. The FLOODLABEL empowers people to protect their property from floods and avoid or reduce damage. The FLOODLABEL is a multi-stage assessment concept for buildings. It shows the potential hazards as well as the risk to the property and recommends measures for self-precaution and the right behaviour before and during an event. The assessment of buildings is conducted by trained FLOODLABEL experts (see Figure 4.1). To train experts, a training concept was developed and tested. A detailed evaluation form is available for the FLOODLABEL experts to assess the buildings. Flood hazards (pluvial and fluvial flooding) were assessed using three risk categories (none, medium, and high). Subsequently, the result was transferred to the FLOODLABEL certificate (see Figure 4.2) and given to the homeowner. A booklet of measures was developed to support homeowners in implementing the recommended measures based on the FLOODLABEL assessment. Flood prevention is an important component of flood risk management. Therefore, the FLOODLABEL should be considered an essential part of the overall strategy for flood risk management.

What are the advantages?

1. The hazard situation is known before flooding occurs
2. Vulnerable points are determined, enabling concrete action
3. Flood prevention measures are supported, reducing damages
4. The population is sensitised to behavioural measures before and during flooding

Information material

- Information on flood hazards
- A booklet of measures gives an overview of behavioural and flood protection measures
- Emergency response plan for homeowners

Further information on the FLOODLABEL can be found via www.floodlabel.info

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4.3 TRAINING OF EXPERTS AND MULTIPLIERS

Sylvia Kruse, Helene Meyer, Mariele Evers

PARADeS was designed and implemented as a participatory research and development project. Therefore, next to scientific output also trainings for experts and multipliers were developed in order to enable tailored and free access to specialist knowledge from various actors and fields of FDRM. Target groups of the trainings are experts and decision makers from public authorities as well as further actors and experts in the field of FDRM. Additional, universities and students are addressed as multipliers of FDRM knowledge.

The trainings were developed within the interdisciplinary project team and in close collaboration between scientists and FDRM professionals from Germany and Ghana. Furthermore, pilot trainings were conducted and used for intensive evaluation and feedback on content, didactics and the provided training material. Based on this, the trainings were revised and transformed into Open Educational Resources (OER) that are free of access and can be shared and adapted under the license of the creative commons.

The OER training modules comprise an introductory module on floods and flood risk management and flood characteristics in Ghana, a module on hydrological and hydrodynamic as well as critical infrastructure modelling, a module on citizen science and participatory methods in data collection, a module on the FLOODLABEL tool as well as a module on collaborative governance. The OER training modules can be accessed here.

In addition to the Open Learning content, a specific training for the FLOODLABLE Ghana was developed (compare Chapter 4.2). The aim is to train FLOODLABEL experts in a two-day training session. Important content relating to FLOODLABEL is taught, and the knowledge acquired by the participants is tested at the end. The target group of the training are NADMO employees (from national, regional, and district levels) who are trained as FLOODLABEL experts to be able to use the tool in practice. The training concept was piloted with the NAMDO employees. Additionally, a pilot case was conducted by University of Cape Coast (UCC) (Geography Department) which approved the applicability of this tool. This concept, together with all FLOODLABEL materials and documents, will be hand over to NADMO (and UCC) at the end of the project to be made permanent.

4.4 LESSONS LEARNED FROM PARADES PROJECT FOR FLOOD DISASTER RISK PLANNING AND MANAGEMENT

Mariele Evers

Flood risk in Ghana is a central and increasing challenge. Thus, appropriate and adapted Flood Disaster Risk Management (FDRM) is of immanent relevance. The purpose of risk management is to reduce the impact of events through modification of the hazard, exposure and/or vulnerability. According to United Nations terminology [67], disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience against and reduction of disaster losses.

On the one hand, FDRM instruments such as flood risk management plans entail certain requirements (as established for example in the European Union by the FDRM Directive (EC 2007) or recommendations for Current Practice in Flood Risk Management in the European Union (EC 2021)). These requirements set standards for, inter alia, using certain return periods for scenarios or establish risk definition. However, on the other hand, risk and vulnerability are context specific, and local and regional conditions have to be considered.

Against this background, we compiled lessons learned from the PARADeS project for Flood Disaster Risk Planning and Management in Ghana in order to support the development of FDRM plans and policies and their implementation. We take into account aspects of prevention (e.g. identification of high-risk areas), protection (e.g. measures to reduce the likelihood of floods in a specific place) and preparedness (in particular, informing and assessing risk on a local scale / household scale and learning about potential measures).

For effective FDRM, it is first important to identify the areas with significant risk. In the PARADeS project we identified hot spots of risk by modelling flood hazards using hydrological and hydrodynamic models, and by simulation of cascading risk with a focus on critical infrastructure and potential consequences with regard to damage and the affected population. We included additional expert knowledge in order to improve the data base and validity of the model results, for example by the application of web-based participatory mapping during workshops with stakeholders, and involved critical infrastructure operators during our analyses, which was a valuable contribution.

The hydrodynamic model that was developed in PARADeS relies on several inputs, including rainfall data (for Accra and Kumasi), discharge data (for the White Volta), a Digital Elevation Model (DEM), cross-sectional data, and land use information used to estimate the Mannings n friction coefficient. The DEM data was derived from DLR TanDEM-X, cross-sectional data was obtained through a combination of in-situ measurements and LIDAR (Light detection and ranging) data, while land use data was sourced from the CORINE Land Use and Cove. We developed hazard and risk scenarios for the urban areas in Accra and Kumasi with return periods of 2, 10, 25, 50, 100, 200, 1,000 years and for the rural area of the White Volta with 5, 10, 25, 50, 100 years.

The model results showed a high level of agreement with the regional expert knowledge as well as with observed data during recent flood events, thus proving the suitability of our models.

Normally, flood hazard and flood risk maps are published in different maps which can be retrieved from the website of one authority. We decided in PARADeS to combine the information on hazard, risk, scenarios or effects of adaptation measures in one tool, the Flood Information System (FIS). Due to the implemented features each user can simulate and learn about different scenarios and cause-effect relationships.

This data and information enable the development of Flood Risk Management Plans either based on a deterministic approach where strategies and measures are defined to meet a certain security level, mostly for a 100-year flood, or based on a risk-based approach, where strategies and measures are defined and prioritized for high-risk areas.

We invested considerable time and resources on the acquisition and validation of data to generate a good data base for the flood modelling. However, by their very nature, the methods used are only approximations to the actual hydrological and hydraulic processes, and results still contain un-certainties. There are certain rules which should be followed to reduce this uncertainty, such as the selection of a suitable model or ensuring that sufficient discharge measurements are available. In the report on "Lessons Learned from PARADeS Project for Flood Disaster Risk Planning and Management in Ghana" we compiled a checklist to reduce the uncertainty of flood model results.

To improve the data base, a citizen science pilot project was set up beside the Odaw river in Accra for the collection of water level/discharge data by community gauges. This pilot has shown high potential not only for data availability but also for awareness raising in the respective communities. However, we also learnt that certain aspects such as timing or coordination of different sub-activities are crucial and should be taken into account to make citizen science projects a success.

In order to increase preparedness and adaptation on a local and household scale we developed an assessment tool which is tailored to the conditions in Ghana, the FLOODLABEL GHANA. This tool helps to identify individual risk and personal adaptation and risk-reduction measures. Based on the model results, specific communities at risk in the Accra Metropolitan Area (AMA) are identified and a set of measures are suggested, for example, for a level of 0.5 m and 1 m protection of a house. Since many communities in the AMA district are affected by flooding it is important to prioritise the actions and define with which communities to start. The analysis showed how the FLOODLABEL can be used to link modelling results to the implementation of flood mitigation measures on a house-hold level in the communities.

In the PARADeS project we experienced the added value of a transdisciplinary approach, for example to increase the data validity, to gain knowledge on human-flood-dynamics through participatory scenario development or to identify suitable adaptation measures. This approach was also appreciated by the participants, as the evaluation results illustrate.

Initiating collaborative approaches requires a thorough identification of who holds what specific stake along both the vertical and horizontal dimensions. The vertical scales represent the level that the strategy or plan should address or at which it should be implemented at, i.e. the local municipal, district, regional or national level. The horizontal level shows the policy sectors that are affected or need to be included for developing or implementing the strategy or plan.

Based on this generic structure, the PARADeS project added to the identification of stakeholders and the analysis of their interactions through the application of Social Network Analysis (SNA). This helps to understand how stakeholders differ in perspectives, interests, capacities and resources as well as knowledge and ideas about FDRM. Therefore, stakeholder involvement processes should be designed to account for these diverse and often diverging perspectives.

In this way, they can set the basis for collaborative governance, where Disaster Risk Management is not only developed and implemented through government agencies, but also actively including stakeholders from non-governmental and civil society organisations, private companies, and the local population. Collaborative governance is regarded as a key mechanism to improve Flood Disaster Risk planning and management as it helps to coordinate meaningful community involvement that both helps to improve FDRM and create risk awareness and self-efficacy; it facilitates the building of a robust framework of accountability and transparency that helps to build public trust; and it fosters inclusivity and collaboration across various stakeholders, also aiming to improve just resource distribution within FDRM processes.

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5. SCIENTIFIC AND PRACTICAL OUTLOOK

Adrian Almoradie, Mariele Evers, Sylvia Kruse, Mawuli Lumor, Charlotte Norman

In the PARADeS research project, professionals from diverse scientific disciplines and practitioners have contributed major works aimed at strengthening Flood Disaster Risk Management (FDRM) in Ghana. What is the scientific outlook, and what were the limitations and the further needs for research? What are practical implications and perspectives in the implementation of FDRM?

We followed the three thematic components of the research project, namely socio, technical and governance components of FDRM.

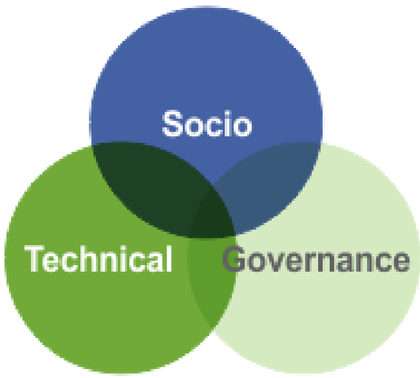

Figure 5.1: PARADeS project components ©PARADeS

Social components of FDRM:

The involvement of stakeholders in collaboratively identifying scenarios and measures, along with community group discussions through social learning, has offered a platform to grasp diverse perspectives, interests, and local knowledge. It is worth to mention that we figured out the heterogeneity of needs between rural and urban areas but within the urban areas. This not only facilitated the research project's activities but also enriched their comprehension and awareness of the issues, causes, effects, and concerns. This approach helps to initiate participation from local affected communities to support regional adapted FDRM.

Community capacity building in the context of FDRM through the FLOODLABEL will strengthen the abilities, resources, and resilience of local communities to prepare for, respond to, and recover from flood-related disasters. This will empower community members to play an active role in disaster risk reduction and management, enhance their knowledge and skills, and foster collaboration and partnerships with local authorities and other stakeholders. The innovation of the FLOODLABEL is a multi-stage assessment approach at the building level. The sustainable implementation of the FLOODLABEL concept is planned by the disaster management organization (NADMO) in Ghana. Additionally, a pilot study to test the applicability of this tool was conducted with student involvement in cooperation with the University of Cape Coast (UCC). The involvement of students as multipliers could support the implementation of the tool. This indicates a significant potential for its practical application and adaptation to different case areas and builds a starting point for further multiplication on the ground. Involving additional multipliers is an effective way to make the instrument even more widespread. The FLOODLABEL concept is a possible way not only to increase risk awareness, but also to ensure individual and collective preventive action within flood prone communities in Ghana.

Technical components of FDRM:

The models employed in this research project have provided us insights into potential consequences of flood impacts in the present and the future. The utilization of open source, such SWAT (hydrological) and the integrated models (hydrodynamic and consequences) within the ProMaIDeS software, along with the outcomes related to hazards and their consequences to people, economy and critical infrastructure, will empower experts to conduct supplementary simulations to support complex decisions with quantifiable arguments. This capability will assist decision-makers and policymakers in selecting the most suitable measures. At the same time, it is necessary to communicate the inherent uncertainties associated with these tools and show the limitations. Only in close collaboration with social and governance aspects will model based analysis be able to support decision making.

The innovative Ghana- Flood Information System (FIS) web-based application publishes the model results, conceptualized together with stakeholders, and is directed at supporting and improving decision-making capabilities for FDRM. Currently, Ghana-FIS emphasis is on informing about hazards (depths and velocity), consequences to people, economy and critical infrastructure under different climate change scenarios and selected measures. There is the prospect of enhancing this tool to include early warning capabilities and transform it into a fully functional decision support system for more extensive utility (e.g. use of multi-criteria methods for consensual selection of measures). The tool will be handed over to the envisaged Flood Early Warning Centre in Accra.

These data and information embedded in the FIS can support both approaches for Flood Disaster Risks Planning (FDRP) (1) a deterministic approach where strategies and measures are defined to meet a certain security level, e.g. for a 100 yearly flood event and (2) also a risk-based approach, where strategies and measures are defined and prioritized for high-risk areas.

For the practical usability of the FIS in decision making processes of FDRM, an extension to other regions in Ghana is necessary, promote and motivate experts and decision makers to utilize the FIS, as well as an inclusion of more data sources for the hydrological and hydro-dynamic modelling. Further, the incorporation of the FIS into a functional Flood Early Warning Centre would strengthen the practical response in case of an emergency as well as for mid-term and long-term strategies and the assessment of adaptation options.

Governance component:

The PARADeS research on the institutional and governance settings in FDRM showed how important trust, accountability and collaboration is for the improvement and implementation of FDRM strategies and plans. This is specifically interesting in the Sub-Saharan African context as both the formal institutional setting as well as informal cultural and socio-economic context are specific and crucial for understanding and overcoming the given barriers and tensions. There are concerns expressed at the local level due to perceived lack of community consultation as well as at the national or transnational level when it is more about the availability of financial and personal resources and the engagement of various stakeholder groups beyond the public agencies. This engagement when performed effectively aims to foster resilience, innovation, and learning, and involves civil society, research, media and the business sector. A thorough stakeholder analysis is conducted across vertical and horizontal dimensions, identifying roles and interests facilitating this process. Engaging stakeholders through participatory approaches enhances representation and fosters diverse perspectives in decision-making. Further, strengthening accountability mechanisms and fostering transparency in resource allocation, building public trust and ensuring efficient disaster management remain a challenge not only for future research but also in policymaking and implementation of FDRM. Embracing inclusivity and collaboration would strengthen disaster risk reduction policies under the United Nations International Strategy for Disaster Reduction (UNISDR) framework.

Examining the three key components of FDRM - social, technical, and governance - offers a comprehensive perspective on the present and future state of flood risk. This comprehensive view facilitates the planning and decision-making processes essential for effectively implementing practical measures to tackle vulnerabilities and challenges in Ghana’s flood risk management.

From a research standpoint, the components of FDRM inherently involve uncertainties including stakeholders' viewpoints, local knowledge and biases, model data and parameters, as well as institutional collaboration in planning and decision-making. Subsequent research should prioritize evaluating these uncertainties and effectively communicating them for practical application.

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