Chapter 9: Increasing Devastating Flood Events in West Africa: Who is to Blame?

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ABSTRACT

In recent years, climate change has become a major worldwide concern. Among its different manifestations in West Africa, flood events are the most devastating. This chapter pulls out the main causes of floods in West Africa from recently published research with the aim of serving as a guide in defining paramount actions to be taken to address flood issues in the region. Inadequate urban planning, poor land management and land occupation, especially in populated areas, amplify climate change impacts and increase flood risk. The situation is likely to worsen in the future. The effectiveness of current adaptation and mitigation measures is analysed and recommendations on possible follow-up actions are given. Given that the cost of inaction might exceed the cost of taking early action, this chapter launches an appeal for concrete actions for flood impacts mitigation in West Africa.

Keywords: Floods statistics, major causes, prevention and mitigation, Early Warning System, West Africa

1- INTRODUCTION

West Africa was struck by unprecedented droughts in the 1970s and 1980s (Lebel et al., 2009, Nicholson., 2001, Omotosho, 2008). This was the period of disastrous droughts that led to famines, and water scarcity in the Sahel region (Lebel et al., 2009). Then, came the 1990s, a decade of transition to a wetter regime (Badou et al., 2016). Since the year 2000, the region has been experiencing devastating flood events (Danumah et al., 2017, Hallegatte et al., 2013, Lamond et al., 2012, Odjugo, 2012) to the extent that the second half of 2000s and the first half of the 2010s could be named the period of the "great flood". Countless number of scholarly works focus on the great drought (Kasei et al., 2009, Tschakert et al., 2010). Projects like the African Monsoon Multidisciplinary Analysis (AMMA) were designed to deepen the understanding of causes and manifestations of the great droughts. Likewise, recent extreme floods events are receiving a growing interest from the West African scientific community. The effects of droughts are more visible in rural areas, but they do not receive the deserved visibility. Floods in urban areas, however, are receiving increasing attention. Hence, several newspapers and countless flood-related studies are being published (Aderogba 2012, Maheu, 2012, Braman et al. 2013, Lokonon, 2013, Okyere et al. 2013, Bonou, 2017) These publications report that Abidjan is among the most vulnerable megacities (Hallegatte et al., 2013). Similarly, Cotonou (Lokonon, 2016), Lagos (Aderogba, 2012, Lamond et al., 2012), Accra (Okyere et al. 2013), Dakar (Maheu, 2012, Ouikotan et al., 2017), Bamako (Lamond et al., 2012), Niamey (Casse & Gosset, 2015) among other west African capitals recorded extreme floods in these past few years.

In the face of the huge flood-related damages (Hounkpè et al., 2016, Hounkpè et al., 2015, Odjugo, 2012), at least two main questions have been raised: (i) what are the main causes of floods? And (ii) what can be done to lessen damages? The first question calls for a careful examination of the factors that trigger floods while the second recommends possible follow-up actions. Studies have identified several causes to floods in the region, some of these causes can be traced to the climate regime of the region. In order to provide a comprehensive summary of the causes of floods, findings published in past and recent literature must be reviewed and verified. This sums up the aim of this study, which is further broken down into the following objectives:

(i) Analyse the past and current flood statistics: flood occurrences, fatalities and damages in West Africa from 1966 to 2017;
(ii) Identify the major triggers (e.g. climate change, land use change, urban planning, lack of drainage facilities) of devastating floods;
(iii) Establish that current research provides solutions for the prevention and mitigation of the effects of floods
(iv) Identify future research priorities in addressing extreme flood issues based on case studies of recent floods in the West African Region

This study is based on a review of flood-related papers with the purpose of filtering research work that has been done so far in the domain of flood risk reduction in West Africa and defining work that remains to be done. Scholarly journals were compiled. During the compilation, special attention was given to the added-value of each paper, the causes of floods identified and the solutions proposed. In addition to the review, flood data on flood occurrence, associated deaths, affected people and total damages over West Africa obtained from EM-DAT database (EM-DAT, 2017) were analysed to generate flood statistics for the 1966 to 2017 period. Then, the main causes of devastating flood events were highlighted to give an idea of challenges to be tackled with the highest priority.

2- HOW DEVASTATING ARE FLOODS IN WEST AFRICA?

In these last few years, West Africa has witnessed a number of flood events with catastrophic damages. Figure 1 shows flood occurrences and the associated number of deaths, the total number of affected people and the total flood-related damages for the period 1966-2017, from the EM-DAT database (EM-DAT, 2017). It can be observed that flood occurrence has significantly increased with pvalue<10-6 for both Mann Kendall and Spearman tests with an estimated Sen Slope of 0.25 (the annual rate of increase in flood occurrence). The mean occurrence of flood per year in West Africa during the 1966-1998 period was 2.8, this number raised to 11.9 between 1999 and 2017. The year 2010 was the worst year with 24 flood events affecting fifteen countries. The number of flood-related deaths in the region has significantly increased (pvalue<10-5) from 35 per year before 1998 to 184 per year after 1998 (in total, 3496 deaths were recorded between 1998 and 2017). The deadliest years were 1999 and 2012 where a total of 520 and 510 deaths were reported respectively. The number of people affected by the different floods in nine countries in West Africa reached 7.7 million in 2015. The total damages obtained from this database must be taken with caution. In fact, zero flood damages were reported in this database for the 2010 floods in Benin while the World Bank reported that the total cost of flood damages in the country amounted to 160 million USD. Nevertheless, West African countries have lost more than 1.3 billion US dollars to floods between 1966 and 2017 and these losses are likely to increase.

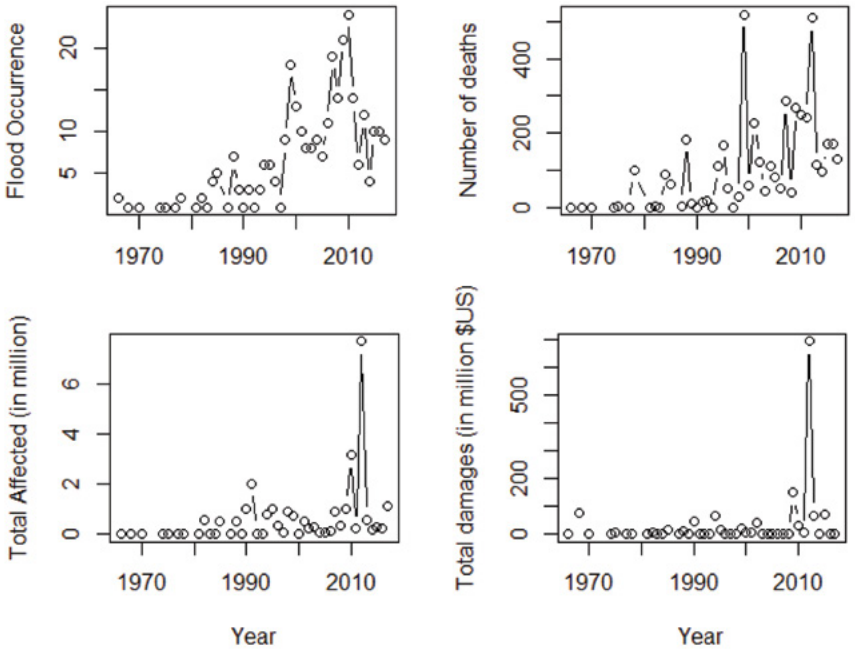

Figure 4: Flood characteristics and the associated lost and damages over West Africa for 1966-2017 (Data was obtained from EM-DAT (2017))

Country based statistics of flood characteristics and the associated damages can be seen in Figure 2. It can be observed that Nigeria is the most affected by flood regardless of the indicators used. It is the country having the highest number of flood events, deaths, affected people and flood damages. More than 10 million people have been affected by floods resulting in 1866 deaths. Based on this observation, we computed the correlation between the population size of each country (obtained from http://www.worldometers.info/, accessed on 05/10/2017) and the corresponding total number of floods during the study period. We found a high and statistically significant correlation of 1% (correlation=0.87 with pvalue= 4.425e-06) between these two variables indicating that floods occur frequently in more populated countries. This may indicate that population growth plays a key role in the increasing flood events observed through West Africa. The total deaths per country, the affected people per country, and the total damages per country were also found to highly and significantly correlate (Pvalue<10-5) with the population size of the countries with correlation value of 0.98; 0.91; 0.92 respectively.

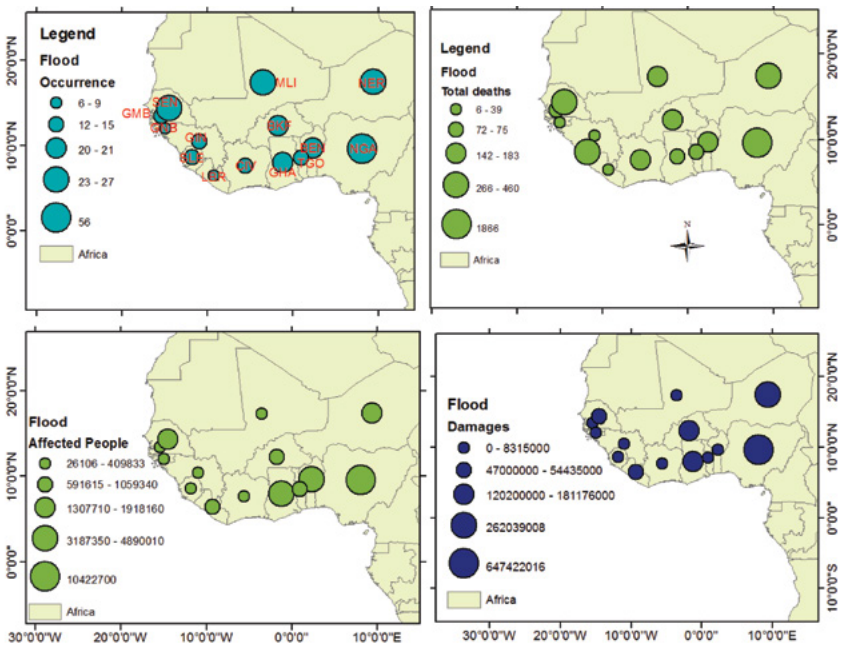

Figure 5: Country based statistics of floods in West Africa during the 1966-2017 (Data was obtained from (EM-DAT, 2017)

3- DOES THE AVAILABLE SCIENTIFIC KNOWLEDGE OFFER A BETTER UNDERSTANDING OF THE CURRENT FLOOD PROBLEM?

Flood-related fatalities in Africa, as well as associated economic losses, have increased dramatically over the past half-century (Di Baldassarre et al., 2010). Identifying the causes of the increasing flood events over the continent and specifically over West Africa remains a challenge. Factors influencing changes in flood risk may include socio-economic conditons (per capita GDP), surface environment (land use and land cover, land management practice, urbanisation, deforestation) and climatic changes (Kundzewicz, Pińskwar, et al., 2013). To this end, an extensive literature review was done to identify the potential causes of increase in flood risk in West Africa.

- Land use and land cover change and population growth (or human induced effects on floods)

As shown in section 0, flood events and flood risks are increasing in West Africa with an associated rise in the number of affected people, deaths and damages. There is an extensive body of literature on flood events in West Africa but the causes of floods in this region are still under debate. Land use and land cover change, mainly, conversion of forest into agricultural lands and agglomeration decrease evapotranspiration (less rainfall is converted into real evapotranspiration) while the building up of surface decrease infiltration, on one hand (more water available for runoff) and increase runoff speed, on the other hand (decrease the concentration time). Many authors in the literature not limited to Di Baldassarre et al. (2010) and Hounkpè (2016) assert that the increase in flood events

in West Africa is mainly due to the change in land use and land cover. These authors argue that the intensive and unplanned human settlements in flood-prone areas appear to be playing a major role in increasing flood risk. According to Di Baldassarre et al. (2010), urban population and flood fatalities increase in the same order of magnitude over Africa continent while no significant climate influence on flood was detected during the period 1985-2009. The government's failure to provide appropriate maintenance for public infrastructure, such as highways, secondary roads, and bridges contribute to the increasing flood vulnerability (WMO, 2009). The analysis of flood recrudescence in Ivory Coast (Danumah et al., 2017, Goula et al., 2011), in Niger (Sighomnou et al., 2013), in Benin (Lokonon, 2016), in Nigeria (Aderogba, 2012, Odjugo, 2012) and many other West African countries reveals that flood risk has strongly increased because of the fast growth of the cities in low-lying and flood-prone areas and waterways. In the Beninese part of Niger basin, the population is largely constrained to settling in the river flood plain due to the fact that most arable land is found along the river (Behanzin et al., 2015).

Poor or inexistent waste management (Lamond et al., 2012, Lokonon, 2016) facilities, poor urbanization and drainage systems (Aderogba, 2012, Ouikotan et al., 2017), lack of funding for flood mitigation measures, absence of integrated flood risk management (Ouikotan et al., 2017, Okyere et al., 2013) are among the major contributors to flood risk in West Africa. The assumption of stationarity of floods when designing hydraulic structures is also a contributing factor to flood risk (Hounkpè et al., 2015, Nka et al., 2015). At the global scale, population growth, socio-economic growth and urbanization are the most important triggers of floods, particularly in developing countries with many low-lying urban areas (Hanson et al., 2011).

- Observed climate change impact on flood

The influence of climate change on hydrological variables such as mean precipitation and heavy precipitation has been detected though a direct statistical link between anthropogenic climate change and trends in the magnitude/frequency of floods (Kundzewicz, Kanae, et al., 2013). The impact of climate change on flood risk is still uncertain (Kundzewicz, Kanae, et al., 2013) and it has not been possible to attribute rain-generated peak streamflow trends to anthropogenic climate change over the past several decades. However, periods of extreme rainfall and recurrent floods appear to correlate with the El Niño phase of ENSO events (e.g. 1982–1983, 1997–1998 and 2006–2007) and generate significant economic and human losses in Africa (Kundzewicz, Kanae, et al., 2013). Li et al., 2016 showed that seasonal changes of flood disasters in various regions of Africa, except North Africa, are closely related to precipitation. Annual flood frequencies, from 1990 to 2014, showed a fluctuating upward trend and were in good agreement with ENSO years. Nka et al., 2015 found significant similarities between flood trends (increasing trends in both flood magnitude and flood frequency) and the trends indicated by certain extreme rainfall indices, namely the amount of heavy rainfall, the maximum amount of rainfall in 5 consecutive days, and the mean daily rainfall. They concluded that this climate signal is possibly another aggravating factor of the increase in runoff coefficients in the Sahelian region. On the Niger basin, Valentin Aich et al., 2015 argue that both past climate change and land use change contribute to flood increase. They also specified that these drivers contribute in roughly equal shares to the observed increase in flooding for Sirba catchment while on the other part of the basin, the results are less clear.

- Future climate change effect on flood

Authors like Kundzewicz et al. (2013) point out that the projected increase in the frequency and intensity of heavy rainfall, based on climate models, should contribute to increase in precipitation-generated local flooding. The impacts of climate change on flood characteristics are highly sensitive to the detailed nature of those changes and presently we have low confidence in numerical projections of changes in flood magnitude or frequency resulting from climate change (Kundzewicz et al., 2013). Projections by (Hirabayashi et al., 2008) indicate an expected increase in the risk of floods in West Africa. Climate change and subsidence can trigger an increase in exposure (Hallegatte et al., 2013). In 2100, the frequency of floods is projected to increase in many rivers in Africa including the Niger river (Hirabayashi et al., 2013). These trends and relative changes for the different catchments of the Niger River basin seem robust. Projected land use change effects on floods were smaller when compared to the effects of climate change in this river basin (Aich et al., 2016).

4- DOES CURRENT SCIENTIFIC RESEARCH PROVIDE SOLUTIONS FOR PREVENTION AND MITIGATION?

To ensure the sustainability of a community, flood management plans should include flood prevention and mitigation measures.

Despite recurring flood-related losses, flood response in West Africa is primarily a post-disaster response that consists

of providing temporary assistance to affected populations. Understanding flood dynamics, in areas where both the environment and hydrological features control water movements, is extremely challenging (Lokonon, 2016, Odjugo, 2012). Flood prevention and mitigation in West Africa has not received the needed attention in current scientific research, despite the significance of the topic. A number of authors, including Lokonon (2016), Odjugo (2012), Nkeki (2013), Komi et al. (2017), Behanzin et al. (2016), Danumah et al. (2016), Valentin Aich et al., (2016), and Atedhor et al. (2010), have commented on the importance of medium to long-range projections on the risk of catastrophic flood as essential tools that would help identify the characteristics of buildings and develop prevention and mitigation options. Yet, high-quality real-time or relatively short-range flow forecasts are considered necessary to mitigate catastrophic losses to life and property (Thiemig et al., 2015).

The Valentin Aich et al., 2016 study issued a warning that increasing flood magnitudes in all parts of Niger river basin have been suggested by the model simulation, however, this warning was not followed by any action until the recent flooding in Kogi State, Nigeria, and in areas around Niamey in late August, 2017. The Niger Basin Authority (NBA) warned that "the rise of the water level in Niamey will spread downstream towards the stations of Malanville at Benin and Jidere Bode upstream of the Kainji dam in Nigeria". The NBA added that "people living near these communities should be particularly vigilant in those areas concerning the risk of river flooding." In addition, rising sea level is likely to lead to an increase in flood events experienced by coastal populations (Komi et al. 2017).
The information above offer viable opportunities to reduce disasters caused by floods in West Africa. In particular, the introduction of flood forecasting and early warning systems, the building of population awareness and preparedness, urban planning and discouraging human settlements in flood-prone areas, along with the development of local institutional capacities, are effective and socially sustainable actions that should be pursued with priority on the African continent (Di Baldassarre et al., 2010).

Given the increasing climate variability, flood disasters are projected to increase in frequency and intensity. The capability to issue preventive solutions and mitigation based on accurate model projections is key to preserving the lives and households of millions of people across West Africa. To support these sustainable actions, the tools and data products (e.g. Drone Africa Services) under development will give, a quantitative portrait of current flood risks in Africa, but also under various intervention scenarios. If adequately communicated to stakeholders, the knowledge generated by these tools should help decision makers to objectively choose between alternative flood protection measures.

Future floods will not necessarily be similar to past ones as both climate and land use are in constant evolution. In this case, the solutions for prevention and mitigation of flood were seen as successful, saving lives and resources, but the need for effective solutions for flood management in Africa can be summarized as follows:

- *produce a future flood risk map, but it is apparent that some areas are more likely to experience more intense or frequent flood events over the next 100 years;*

- *plan adaptation strategies for climate change impacts and actions to reduce greenhouse gas emissions;*

- *prepare a simplified hazard/disaster management cycle, with stages before and after flood events relating to flood prevention, mitigation, emergency response and recovery;*

- *attempt to prevent hazards/disasters through government flood-control engineering policies;*

- *structural flood prevention and mitigation options should include appropriate land use planning, enforcement of building codes to avoid construction in flood prone sites, insurance schemes, and effective flood forecasting, warning and evacuation procedures (Grabs et al., 2007);*

- *provided high quality data is available, computer models can simulate flood extent and water velocity by means of a hydrodynamic model in order to dynamically simulate flood propagation in the region under future flow and precipitation conditions;*

- *Improve the accuracy of weather forecasts to help West African cities and communities to build resilience against climate change;*

- *"Effective hydromet services, such as advanced weather and climate forecasting or simple - and sustainable river-level gauges, ensure that communities have the early warning signals needed to prepare before disasters hit. Climate services permit government agencies to effectively plan for climate change based on the latest information,*

and businesses in climate-sensitive sectors to incorporate timely, accurate data in the decisions that affect their industry." Petteri Taalas, Secretary-General, World Meteorological Organization.

Before moving onwards from this initial description of flood, scientists should initiate dialogue with different sectors; emergency response, humanitarian, insurance; to determine sector-appropriate indices of flood based on the relevance and importance of different flood characteristics (e.g. magnitude, duration), and to determine the region over which flood risk should be forecasted. These efforts focus on institutional capacity building, systems modernization, and service delivery. Priority should be given to research relating to flood prevention and mitigation response.

5- DO FLOOD EARLY WARNING SYSTEMS (FEWS) REALLY EXIST AND IF THEY DO, ARE THEY ADEQUATE?

There are a number of ongoing institutional flood forecasting initiatives in West Africa. Thiemig et al., (2011) made an inventory of these existing institutions. From their review on the current status of flood forecasting and warning in West Africa, it appears that the main providers of flood forecasting information in West Africa include the NBA, the Volta Basin Authority, the Université Cheikh Anta Diop, the AGRHYMET Regional Centre and the African Centre of Meteorological Applications for Development. They also pointed out that providers of flood forecasting information are part of a network and that end-users of the information provided include disaster management agencies/units, government and national water resource agencies, national hydrological services (NHSs), national meteorological services, basin authorities, research centers and universities, ministry of transport and navigation services.

Wherever they were effectively implemented, flood early warning systems yielded substantial reduction in flood fatalities (Di Baldassarre et al., 2010). So, why are flood-related fatalities still increasing in West Africa albeit the availability of flood forecast and early warning institutional infrastructure? The answer is that flood forecasting systems do not exist per se in many West African countries (WHO, 2006), besides, there is little literature on the topic (e.g. (Coughlan de Perez et al., 2017, V. Thiemig et al., 2015, Vera Thiemig et al., 2010, 2011) and very low or non-utilization of the results of climate research (Tarhule & Lamb, 2003). Before discussing the dissemination of forecast and warning information, it is worth questioning the availability of the key elements required for the production of flood forecasting and early warning information. A flood forecast system requires basic data to operate (V. Thiemig et al., 2015): (i) a validated hydrological model, (ii) historical hydro-meteorological observations, including flood archives, and (iii) near real-time meteorological forecast.

A critical evaluation of the availability of the above mentioned three key inputs needed for setting up a flood forecast system shows the following. (i) A decade ago, none of the West African NHSs stated that hydrological flood forecasting models could be used for weather forecasting (WHO, 2006), there is, however, a need for technical expertise in flood modeling (Vera Thiemig et al., 2011). (ii) Due to the declining number of rain gauging and climate stations in the region, most of the national hydrometric and meteorological networks do not meet the WMO standard; therefore, historical hydro-meteorological data is sparse. Reanalysis and remote sensing climate and hydrological data (McCabe et al., 2017) partly compensate for this gap, however, ground based observation is still crucial for the evaluation and validation of this data (Poméon et al., 2017). As for setting up a West African flood archive, initiatives are still awaited. (iii) So far, the meteorological forecast from the European Centre for Medium-Range Weather Forecasts has provided satisfactory results in previous African flood forecast studies.

In the light of the current status of flood forecast in the region and at the request of many West African institutions involved in flood forecasting activities (Vera Thiemig et al., 2011, WHO, 2006), the needs for effective flood forecasting and early warning systems in the region can be summarized as follows:

- expand the mandate of national hydrological services to add flood forecasting activities to their traditional role of collecting data for water resources assessment;
- strengthen the technical capacity of NHSs in flood forecasting (hydrological modelling and interpretation of the resulting information);
- build up and strengthen a West African hydro-meteorological observation network. Initiatives like the Observation Network of the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL, wascal.org) program support this objective;
- the NHSs and flood forecasting institutions should advance towards the use of ensemble prediction systems in flood forecasting as it represents the state of the art in flood forecasting science (Cloke & Pappenberger, 2009). Furthermore

its applicability in the regions has been sufficiently proven (Thiemig et al., 2015, Thiemig et al., 2010). Monthly and seasonal hydrological predictions (as it is currently performed by flood forecasting institutions), although still valid (Tall et al., 2012), are of limited application for flood preparedness (Coughlan de Perez et al., 2017);
- increase financial support to institutions dealing with flood forecasting as most of their initiatives are severely hampered by a lack of financial resources.

Poor delivery or communication of flood information to end-users undermine its effectiveness (Ocampo & Johnson, 2004). A strong collaboration between data providers and end-users is therefore necessary, this also calls for the development of user-oriented products like the recently developed flood forecasting application, Wetln App, for Nigeria.

6- CONCLUSION

Poor urban planning and climate change have been highlighted by many studies as the major cause of flood hazards. Scientific products available in the region include maps of flood prone areas, flood forecasting schemes and future flood projections under known flood drivers like climate and land use change. Equally important scientific solutions include proper design of drainage systems and efficient urban planning. Some of these products are somewhat flagged to be issued at the national or continental scales and are of limited applicability at the decision-making level. Scientific research should therefore offer tailored flood-related products for use at the community and district levels. More emphasis should be placed on transfer and use of research results.

More importantly, actions do not follow awareness about flood risks. The weakest aspect of flood risks reduction in West Africa is the capacity to take concrete actions. This calls for stronger collaboration between researchers and action-takers. Future reflections and research should focus on:

(i) Who must take action with regards to the area where intervention is needed?
(ii) How would actions be efficiently implemented?
(iii) How will funds be raised for flood risk alleviation?