Chapter

Flood Disaster Hazards; Causes, Impacts and Management: A State-of-the-Art Review

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Abstract

Floods are among disasters that cause widespread destruction to human lives, properties and the environment every year and occur at different places with varied scales across the globe. Flood disasters are caused by natural phenomena, but their occurrences and impacts have been intensified through human actions and inactions. The practice of flood disaster management have evolved over the years from traditional approaches of ad-hoc response measures to integrated approaches involving technologically advanced tools in flood disaster awareness, preparedness and response measures. This chapter proffers understanding into flood disaster awareness, preparedness and management, mitigation and adaptation strategies. Most importantly, the chapter presents a review on the relevance of modern technological tools namely Geographic Information System, Remote Sensing, Internet of Things and Big Data, that are available to flood managers, in the creation of efficient early warnings and Flood decision support systems that elevates the resilience of societies to flood disasters.

Keywords: flood disaster, disaster risk awareness, disaster risk preparedness, disaster management, early warning system, resilience, technology

1. Introduction

Disasters can result from forces of nature which may be aided by human actions. Some disasters build up slowly while others may happen suddenly and unexpectedly. Flood disasters can be classified among the quick and sudden disaster types, but are among few in this category that can be well predicted, anticipated and controlled to a great extent.

Floods, like other disasters, do not qualify to be labelled 'disasters' by the mere virtue of their happenstances. They do become disasters when they cause damage or adverse effects to human lives, livelihoods and/or properties. Floods are probably the widest spread among the various disaster events that occurs in most countries and causes the most deaths [1]. Floods, like other disasters, have the ability to cause widespread disturbances in communities, and alter the way of life of people in the affected areas.

The word flood originated from the old English word 'flod' akin to the German word 'flut' and the Dutch word 'vloed' seen as inflow and float of water [2, 3]. The Oxford Reference Dictionary (ORD) defines flood as an overflowing or influx of

water beyond its normal confines. Floods usually happen when the volume of water within a water body, say, a river or a lake, exceeds its total carrying capacity and as a result, some of the water flow outside the normal perimeter of the water body. Floods occur in almost every part of the world with different intensities and effects. Some of the most notable floods that have occurred include the 1981, 1991 and 2002 floods along the Chiang Jiang (Yangtze) river in China, the Mozambican floods in 2000, the 1983 and 1993 floods on the Mississippi river [2].

In the summer of 2005, the remarkable flooding brought by Hurricane Katrina which caused more than $ 108 billion in damages, constitute the costliest natural disaster in U.S. history [4, 5]. Identified different types of floods namely riverine floods, localized and urban floods, normal flood (e.g. 1-year flood), medium flood (e.g. 5-year flood), severe floods, and catastrophic floods. It is indicated that floods can also be distinguished by their style of occurrence [2]. Flash floods occur when water quickly sweeps over an area which is difficult to deal with and it is not easy to predict the amount of rain expected within the spatial area over a short period of time [2].

Regional floods occur when rain falls over a large area for days or weeks causing river levels to rise quickly and fall slowly usually inundating large areas and causing widespread economic losses [6]. Flash floods are also referred to as upstream floods and regional floods, downstream floods [7].

There are varied effects of floods. The primary effects of flooding include physical damage to buildings and weakening of structures [2]. There are instances of loss of human lives and livestock, and the outbreak of disease epidemics. Other effects include instant losses of entire harvest as in the Mozambique flood in 2000 and northern Ghana floods of 2007. Whilst the effects of floods have come to be highly perceived in the negative, it is also true that floods are not entirely of damaging impact on human beings. Flooding can be beneficial such as making the soil more fertile and providing nutrients. Periodic flooding was essential to the development of some of the ancient civilizations especially those along the Tigris-Euphrates rivers, the Nile river, Indus river among others [2].

2. Causes and impacts of flood disasters

2.1 Cause of floods

Floods happen when soil and vegetation cannot absorb water from downpours. Floods also occur when a river outbursts its banks and the water spills onto the floodplain. Natural processes such as hurricanes, weather systems and snowmelt can cause floods. Other floods following tsunamis and coastal surges have natural causes like earthquakes in the seabed and high tides attributed to the pull of the moon [2]. There are many human-induced causes of flooding.

Urbanization has also become a major cause of flooding in cities [8], such that, a river is more likely to flood when its drainage basin is in an urban area. Inadequate drainage in some urban areas is a major cause of flooding [3], while in others, it is the lack of proper management of the drainage systems. Unplanned urban living has been identified as a significant contributor to flooding events in many developing countries. In a study into causes of flooding in Asamankese in the Eastern region of Ghana by [9] for instance, a resident succinctly summarises the problems as below;

> *[T]he main problem in Old Zongo and Abaase areas is the gutters. The gutters are not enough to carry the water when it rains heavily, and secondly, they pour*

> *so much rubbish in the gutters, so some of the gutters are also full of rubbish. So, when it rains heavily, where will the water go, it must flood the area. ....the way we build in this area too is a problem. I even think government is not hard on people so we just build anyhow in the waterways. We in this area also experience floods but it is not serious like in Old Zongo areas, that is why we are always trying to tell people here not to build in the waterway, because of what is going on in Old Zongo and Abaase.*

This summarises the major contributions of improper managed urbanisation to flooding, a phenomena which characterises many developing countries. In Ghana, for example, perhaps the most devastating flood in the history of the country occurred in its capital, Accra, on 3rd June, 2015 where 159 people lost their lives and several people rendered homeless [10]. NADMO [11], suggests that although Ghana is vulnerable to certain disasters, flooding has become the major disaster the country has suffered in recent years especially in its urban areas due to improper management of these spaces [12].

Figure 1 shows the nature of some gutters in the urban areas of Ghana. **Figure 1** shows a partially completed drainage in the flood prone zone of Asamankese, in the Eastern region of Ghana. Most of the gutters in the community, like **Figure 1**, are left open and easily gets silted by inflow of sand and other waste materials. The situation of improper management of urban spaces is worse in the major Central Business Districts in many developing countries. Plastic wastes and other debris have been left to clog urban drainage which results in flood disaster when heavy rains are experienced.

2.2 Impacts of flood disasters

What flood events share in common, is their ability to cause widespread community disruption, displacement, economic loss, property damage, deaths, injury as well as profound emotional suffering. Infrastructure and property, agricultural endeavours as well as historical and cultural sites may also be affected in flood disasters.

According to the United Nations Regional Coordinator in Dakar (October 2007) the worst flooding in 30 years that battered West Africa from July 2007 caused more than 210 death and affected more than 785,000 people [12].

The aftermaths of flood disasters in Ghana are the large-scale destruction of infrastructure, displacement of people from their dwellings, the loss of human lives, outbreak of diseases and water-borne infections, chemical exposure due to toxic pollutants being released into flood waters, huge loss of investments among other things.

Africa, which is one of the poorest continents in the world (in terms of GDP growth and income) has seen an increase in flood disasters in recent times [9]. For instance, torrential rains and flooding affected 600,000 people in 16 West African nations in September 2009 [13]. Countries with most devastating impacts were Burkina Faso, Senegal, and Niger. Another instance include the 2007 floods that displaced more than a million people in Uganda, Ethiopia, Sudan, Burkina Faso, Togo, Mali, and Nigeria, which claimed over 500 lives, and the 2008 floods in Mozambique which killed seven people and displaced tens of thousands residence [14]. Heavy seasonal rainfall starting in December 2014 also caused flooding in southern Africa [15]. As of January 2015, 135,000 people were affected by flood hazard in Malawi, Mozambique, Madagascar and Zimbabwe [15].

The impact of flooding varies both spatially and temporally. It could also be direct or indirect. Rahman [16] indicated that the direct impacts of floods are

Figure 1.
Showing a partially completed drain in the Asamankese community, Eastern region of Ghana. Source: Author.

closely related to the depth of inundation of floods water. The extent of a flood has a direct relationship for the recovery time of crops, pastures and the social and economic dislocation impact to populations. The impact of floods is considered far reaching with the aftermath effects such as flood-induced disease epidemics. Disease outbreak is common, especially in less developed countries. Malaria, Typhoid and Cholera outbreaks after floods in tropical countries are also common [17]. [9] further stated that physical damage to property is one of the major causes for tangible loss in floods. This includes the cost of damage to goods and possessions, loss of income or services in the floods aftermath and clean-up costs. Some impacts of floods, on the other hand, are intangible and are hard to place a monetary figure on. Intangible losses also include increased levels of physical, emotional and psychological health problems suffered by flood-affected people.

According to [15] the cumulative number of people affected by rains and floods in 2007 in Southern Africa was more than 194,103 persons. This included 60,995 in Malawi (Mostly damage to property and crops), 94,760 people in Mozambique (all were evacuated into resettlement camps); more than 16,680 in Zambia (1890 persons had temporary accommodation, the rest were taken in by host families); and 15,168 in Zimbabwe. An estimated additional 4000 people had been affected in Lesotho and another 2500 persons in Swaziland.

Extreme events affect both the formal and informal economies, making it difficult to assess impacts which include direct and indirect ones. Depending on how well they are constructed and the severity of the event, buildings may be partially or totally destroyed by flooding. A look at **Figure 2** will explain the partial damage that often happens to buildings as a result of flooding.

Flood destructions also hit roads and cause delays to infrastructure development initiatives and political processes [18, 19] observed that the economic impact of natural disasters shows a marked upward trend over the last decades. The hazards

Figure 2.
Depicting the impact of flood events o residents' household in Asamankese, Eastern region of Ghana. Source: Author.

tend to hit communities in developing and least developed countries more. Flood disasters have led to the loss of human life, destruction of social and economic infrastructure and degradation of already fragile ecosystems [20]. It follows therefore that social impacts include changes in people's ways of life, their culture, community, political systems, environment, health and wellbeing, their personal and property rights and their fears and aspirations.

Rahman [21], established that social impacts of floods cause significant problems for the long term functioning of specific types of households and businesses in affected communities. The type of construction influenced the extent of flood damaged (e.g. thatched homes versus concrete high rise buildings will experience different degrees of impact). It follows that vulnerability is a key element in assessing the impact of floods. Different population segments are exposed to varied relative risks because of their socioeconomic conditions of vulnerability. Because of this, disaster reduction has become increasingly associated with practices that define efforts to achieve sustainable development. The links between flood disaster and economic systems, have become another pillar of consideration for sustainable development. Floods, however, cannot be totally prevented but their devastating impacts can surely be significantly minimized if advance warning of the event is available.

3. Flood disaster risk awareness

Disaster risk awareness is the extent of common knowledge of a person or group of persons about disaster risks, the factors that lead to disasters and the actions that can be taken individually or collectively to reduce vulnerabilities to hazards. It also includes the need to build and increase the knowledge and understanding of the many issues about disaster risk reduction, to build the capacity of the people who learn and teach others about the disaster [9]. Changes in patterns of human behaviour and decision-making at all levels of government and society could, therefore, lead to a substantial reduction in disaster risk [22]. In this respect, recent experience has shown that public awareness of natural hazards and disaster risk reduction education constitutes a foundation and pre-requisite for effective catastrophic risk management

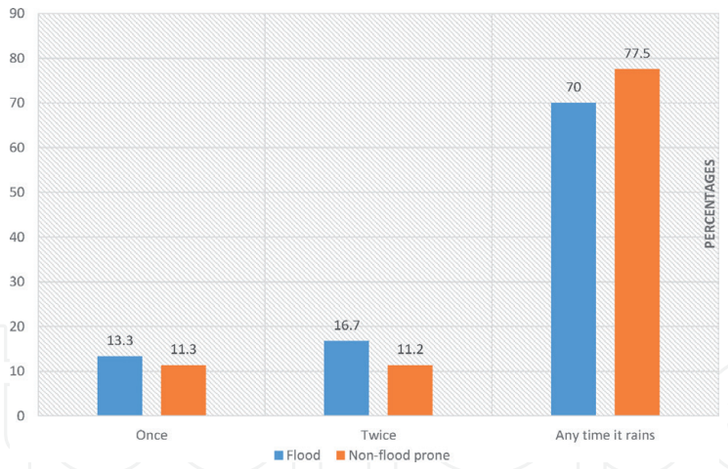

Figure 3.
Showing respondents awareness to flood disaster risk at Asamankese, Eastern region, Ghana. Source: Author.

strategies at country and regional levels. More importantly, by influencing human actions and perceptions through societal behaviour and behavioural adaptation, information and education can increase flood risk awareness and play a more effective role in reducing the costs of catastrophes associated with natural perils [22].

To proffer an understanding on the flood risk awareness of residents in the Asamankese Municipality of Ghana, [9] surveyed some residents and sought to know how likely the area was susceptible to flood through the major rainy season from March to July. **Figure 3**, which summarises the respondents result, pointed out that an overwhelming proportion of respondents (70.0% and 77.5% within the flood prone and Non-flood prone zones respectfully) indicated that flooding has become a regular phenomenon, and the community was likely to be flooded every time it rained.

Awareness is a very crucial element for a society to effectively adapt to a flood risk. As stated by [23] awareness is diminished when the provision of an appropriate information is minimal or when memories of past experiences or events are diminished. Awareness can generally be uplifted through efforts that are centred on local issues, contain the simple solution to reduce the flood risk and are repeated on a regular basis [24].

Scholars like [25] posit that worry is an important risk characteristic that serves as a normative value for awareness. Society can be aware of a flood risk, however, if it is not afraid of the risk, it will not take any action to prepare for it. A higher level of worry is more likely to result in a higher level of awareness and preparedness. There is a positive correlation between these two variables. This was reinforced by [26] with their assertion that most people become aware and prepared for disasters based on their previous personal experiences with flood disasters. Early warning information can, therefore, allow the disaster managers to be pre-informed and take steps which may significantly reduce the loss of life and damage to property.

4. Flood disaster preparedness and resilience strategies and practices

The argument now is that adequate preparation can make it possible to significantly reduce the impacts of flood disasters through a good understanding of preventive action as well as knowledge of some life-saving techniques during disasters [27]. Nowhere has the issue of floods become a developmental issue than in poor and developing countries where systemic problems and institutional constraints

have increased vulnerability (social, economic and physical) to flood risk and thus, reducing resilience to flood disasters.

Disaster preparedness is defined as the state of taking measures to reduce to the minimum level possible, the loss of human lives and other damages from flood disasters through prompt and efficient actions of response and rehabilitation. That is, preparedness is to put in place the necessary measures for effective and timely response to an event. The objectives of preparedness are to ensure that appropriate mechanisms and resources are in place to assist those afflicted by the disaster and enable them to help themselves [9].

Flood disaster preparedness consists of a wide range of activities and protective measures that might be instigated from the physically or procedurally. Preparedness is very important in the disaster management process, and includes the knowledge, capacities, activities and measures carried out in advance by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of imminent or current disaster situations or conditions.

The [26], conceives preparedness as a medium-term plan that involves the development and the implementation of disaster management plans. It involves the development and implementation of early warning systems, resource inventory and stockpiling of resources, coordinating of agencies and ensuring evacuation plans work. Preparedness is seen as tools for ensuring the effective coordination and enhancement of capacities to prevent, to protect, to respond to, recover from and mitigate the devastating effects of natural and man- made disasters [9].

Apart from personal experiences informing residents' awareness and preparedness towards flood disasters, external factors such as occupation, level of education of an individual, radio programs and community meetings serve as conduits for disseminating flood information. Hence, these factors may act to increase awareness and preparedness levels to flood disasters.

Studies show that residents' awareness of flood disaster is usually high. For instance, in [9]'s study of residents' level of flood disaster awareness in Asamankese, in Ghana, showed that more than 65 percent of residents in both the Flood prone and Non-flood prone settlements ranked themselves to be at a high risk of flood disasters. Furthermore, the study showed that, the awareness of human factors that exacerbate their risk to flood was also high. However, preparedness of residents' in most cases were poor, and in Asamankese, like in other developing countries, victims of flood had to usually depend on extended social networks, and government institutions for support to regain their livelihoods after being hit by flood events, a situation which results from their ill preparedness to flood disasters especially financially.

5. Strategies and technologies for improved flood disaster management

5.1 Flood disaster management strategies

Flood Disaster Management Strategies refer to a bundle of processes and activities that are aimed at reducing the overall impacts of floods on societies. Flood management needs to be considered within the overall national development planning strategy of every country and must involve strategic institutional arrangements and collaborations for a sustainable flood management.

The management of floods as problems in isolation almost necessarily results in a piecemeal, localized approach (World Meteorological Organization [28]). The flood disaster management process should also be coordinated with efforts made

in closely related fields. For example, the disaster mitigation process should consider human health impacts during flooding (e.g. cholera, malaria), thereby more effectively address a health issue that arises during and after flooding [28].

The management of floods takes several approaches ranging from traditional approaches to integrated approaches. The traditional management response to a severe flood was typically an ad- hoc reaction, the quick implementation of a project that considered both the problem and its solution to be distinct and self-evident. Traditional approaches usually gives no thought to the consequences for upstream and downstream flood risks [28]. Thus, flood management practices have largely focused on reducing flooding and reducing the susceptibility to flood damage. Traditional flood management has employed structural and non-structural interventions, as well as physical and institutional interventions. These interventions have occurred before, during and after flooding, and have often overlapped.

There has been a paradigm shift in flood management. Traditionally, controlling floods has always been the main focus of flood management, with the emphasis on draining flood water as quickly as possible, or storing it temporarily, and separating the river from the population through structural measures such as dams and levees [28].

The concept of integrated flood management has led to a paradigm shift: absolute protection from floods is a myth, and focus should aim at maximizing net benefits from the use of flood plains, rather than trying to fully control floods [28].

A proactive approach towards the management of floods over a traditionally reactive approach is rapidly gaining recognition among flood managers. The proactive approach does not treat floods only as an emergency or an engineering problem, but as an issue with social, economic, environmental, legal and institutional aspects. The proactive approach is not limited to a post-event reaction but includes preparedness (including flood risk awareness) and response measures to flood management at different stakeholders' levels [28].

Recent calls in flood management are geared at taking a transboundary approach since floods do not respect borders; neither national nor regional or institutional [29]. The great advantages of transboundary cooperation are that it broadens the knowledge/information base, enlarges the set of available strategies and enables better and more cost-effective solution. Furthermore, widening the geographical area considered by basin planning enables measures to be located where they create the optimum effect [29].

5.2 Early warning systems

The term 'early warning' is used in many fields to describe the provision of information on an emerging perilous circumstance where that information can enable action in advance to reduce the risks involved. The early warning system comprise the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations that are threatened by hazards to take necessary preparedness measures and act appropriately in sufficient time to reduce the possibility of harms or losses [30].

Early warning systems exist for natural geophysical and biological hazards, complex socio-political emergencies, industrial hazards, personal health risks and many other related hazards. Studies have demonstrated that disaster prevention can pay high dividends and found that for every Euro invested in risk management, broadly 2 to 4 Euros are returned in terms of avoided or reduced impacts on life, property, the economy and the environment [31]. Early warning systems can be set up to avoid or reduce the impact of flood hazards and other disasters such as, landslides, storms and forest fires and volcanic eruptions. The significance of an

effective early warning system lies in the recognition of its benefits by the members of the general public.

Early warning is a major element of flood disaster risk reduction. It saves life and reduces economic and material losses from flood disasters. To be effective, community-based early warning systems need the active involvement of the community people, a strong public education on and awareness of risks, an effective communication system ensuring a constant state of preparedness [31]. Early warning systems contribute with other Disaster Risk Reduction (DRR) interventions to protect and support sustainable economic development and early detection of undesirable situations. The society benefits from early warning systems if they are in place. Many governments have failed to take early warning into account while formulating their development and disaster risk reduction policies. Subsequently, it results in heavy losses to human lives and economic entities when disasters strike [31].

A people-centered early warning system necessarily comprises four key elements: (I) knowledge of the risks; (II) monitoring, analysis, and forecasting of the hazards; (III) communication or dissemination of alerts and warnings, and (IV) local capacities to respond to the warnings received. The expression "end-to-end warning system" emphasizes that early warning systems need to span all steps from hazard detection to community response. It is essential to link downstream communities and upstream communities for the effective operation of an early warning system [31]. There are several instances where early warning systems have helped to mitigate the impact of disasters. As an example, the Bangladesh cyclone preparedness program has successfully warned, evacuated and sheltered millions of people from cyclones since its inception in the early 1970s by the International Federation, the Bangladesh Red Crescent Society and the government of Bangladesh. In the Caribbean, during 2004's hurricane season, most countries successfully alerted their populations to approaching storms and saved many lives as a result. The key to their success was putting people, not just technology, at the centre of their warning systems. As a result of early warning systems, there were no deaths reported in La Independencia, Guatemala during the hurricane season in October 2005 [26].

The importance of early warning has been underlined in various UN General Assembly resolutions as a critical element of disaster reduction. Early warning received very high attention after the 26 December 2004 tsunami, when it became clear that a tsunami warning system and associated public education could have saved thousands of lives. The UN Secretary-General in his report; *In Larger Freedom: Towards development, security and human rights for all*, proposed that the United Nations system should take a leadership role in developing comprehensive global capacities for systematic people-centered early warning systems, which would cover all hazards for all countries and communities. Subsequently, he requested that a global survey is undertaken, with a view to advance the development of a Global Early Warning System (GEWS) for all natural hazards [32]. Thus early warning systems are very important for disaster management and should be a priority at global, national and local levels.

5.3 Flood disaster mitigation strategies

Flood Disaster Mitigation measures tend to be potentially more efficient long term sustainable solutions to water-related problems and should be enhanced, in particular, to reduce the vulnerability of human beings and goods exposed to flood risk. Flood forecasting and warning is a prerequisite for successful mitigation of flood damage. In the field of environmental engineering, flood mitigation involves the managing and control of flood water movement, such as redirecting flood run-off through the use of floodwalls and flood gates, rather than trying to prevent

floods altogether. It also involves the management of people, through measures such as evacuation and dry/wet proofing properties for example. The mitigation of flooding can be done on an individual, community and at city authority or national levels.

5.4 Flood disaster adaptation strategies

Flood disaster adaptation refers to actual adjustments made that are geared towards mitigating the severity of flood disasters. Flood disaster adaptation strategies vary from before flood adaptation, during flood adaptation, to post flood adaptation strategies. It also ranges from individual, community, to citywide adaptation strategies. Discussions on flood adaptation strategies pointed out that embankments, for instance, either concrete or sandy may be constructed to prevent water from entering residential houses [33]. Adaptation options that would be effective for flood disaster in developing nations include Environmental policy reforms, changes in urban and housing design, removal of laws that can inadvertently increase flood vulnerability [34]. Capacity building is also required to integrate climate change and its impact on urban development planning, engaging local communities, raising public awareness and education on climate change and enabling wider representation at stakeholder meetings. Planting of vegetative cover to reduce runoff speed, terracing hillsides to slow flow down hills as well as control of man-made channels to divert flood water among others, serve as adaptation strategies. Generally, adaptation strategies adopted in flood disasters range from structural to non-structural [35].

5.5 Monitoring, evaluation and mainstreaming of flood disaster management

Being able to count on institutionalized capacities to mobilize and coordinate resources when and where they are needed is crucial in all phases of the disaster cycle, sometimes with very little room for delay or errors of judgment. Coordination among agencies and stakeholder groups is important for flood mitigation, in particular, the design and execution of programmes and policies to help address underlying causes of extreme vulnerability [36]. Monitoring of activities is necessary because there is often the need to link responsibilities and budgets for programmes over time. The performance of institutions and organisations responsible for disaster management should be monitored and evaluated on a regular bases. The relevance of monitoring and evaluation as a means of reducing flood disaster events cannot be overemphasised.

The capacity to monitor and evaluate flood prevention, mitigation, relief and recovery operations and institutional arrangements would create opportunities for learning and improve the accountability of authorities [36]. Monitoring is a key element in pre-flooding, flooding and post flooding stages of flood disaster management. Evaluation goes hand in hand with monitoring to assess the impact of flooding and the effects of key interventions engaged in mitigating the impact of flooding on people, infrastructure, and the environment in general. In a study on the environmental aspects of integrated flood management, [28], noted that adaptive management requires continuous monitoring of the state of the environment and evaluation at regular intervals.

The importance of monitoring has been recognized from various perspectives [28] Pre-plan monitoring of various natural processes provides the basic input for assessment of resource, risks and development options. Monitoring at a development planning level is based on actions taken in line with selected plan and factors of environmental impacts indicated in environmental assessment at the strategic

level [28]. In the context of awareness of flood hazards, monitoring encapsulates awareness of causes and how these causes change over time, knowledge of interventions and how these interventions are shaping the frequency and nature of flood events in an area. Monitoring is essential in flood management from a first-hand point of providing timely and efficient early warning information. Immediate and post-implementation monitoring is important in order to assess whether the flood management measure has succeeded [28].

Mainstreaming of disaster risk reduction into development planning, policy, and implementation should be at the heart of every sustainable Development Planning agenda. Disasters, such as floods, have an enormous impact on development. There is, therefore, the need for mainstreaming disaster planning into development planning. The importance of mainstreaming is also recognized by the Hyogo Framework for Action (HFA) adopted at the World Conference for Disaster Risk Reduction (WCDRR), where integration of disaster risk reduction into the development programmes is a priority [5]. There has been increasing recognition by both governments and donors for the need to mainstream disaster risk reduction into development planning [37]. Mainstreaming disaster planning into development planning considers risks emanating from natural hazards in medium-term strategic development frameworks, in legislations and institutional structures, in sectoral strategies and policies, in budgetary processes, in the design and implementation of individual projects and in monitoring and evaluating all of the above [37].

5.6 Sustainable flood management

The concept of sustainable development is firmly rooted in all flood management. Sustainable flood management involves: ensuring quality of life by reducing flood damages but being prepared for floods, mitigating the impact of risk management measures on ecological systems at a variety of spatial and temporal scales, the wise use of resources in providing, maintaining and operating infrastructure and risk management measures, maintaining appropriate economic activity [38]. Sustainable flood management as a concept is not new, its methods have been practiced on many continents for years [39]. With increasing scrutiny of traditional engineering solutions, there is a growing realisation throughout the world that there is a huge and urgent need for pro-active and sustainable flood management solutions.

The notion of sustainability in the context of flood management is still rather ambiguous but generally embraces economic, environmental and social objectives. Sustainable flood management therefore refers to the provision of possible social and economic resilience against flooding, by protecting and working with the environment, in a way which is fair and affordable both now and in the future [40]. In practice a sustainable approach should integrate a range of flood management requirements using best practices and involving the economics of a scheme, good planning, understanding flood generation processes, protecting natural environments and working with communities [39]. Sustainable flood management is, therefore, an integrated set of procedures linked into a physical catchment.

6. Technological advancements in flood disaster management

Advanced technologies have been developed and integrated into higher institutional level decision support systems to aid the prediction, monitoring and management of flood disasters in some countries. These advanced flood decision support systems' architecture include technologies such as Geographic Information Systems, remote sensing and photogrammetry, and hydrologic models.

The Flood Decision Support System (FDSS) refers to interactive computing environment designed for specific contexts which include interlinked models/ analytical tools, databases, graphical user interfaces and other systems. The FDSSs according to [41] have the potential to improve flood disaster assessment and mitigation through improved data collection and rapid dissemination of flood information to affected areas. For an effective FDSS on the technology aspect of disaster management, analysts have to ensure effective interoperability of the technologies. This will ensure that, all aspects of the technology that singularly may be responsible for data capture, storage, manipulation, analysis, retrieval or display of information, work in a smooth interwoven network and relay information to other parts of the system without technical hindrances to ensure the overall goal is achieved.

There are three main components to the Flood Disaster Support System. These include the Database component, the Modelling component, and the Display component also known as the Graphical User Interface (GUI) component. The Database component of the FDSS comprises the data used in the modelling functions. This component uses to tools to capture and store flood related data. Some data stored include historical rainfall data, geological data, soil and ecological data, population data, boundary and administrative data. Tools used in data capture for the Database varies depending on the data to be captured. For example, Remote sensing techniques are used to capture satellite data on flood zones, flood buffer zone monitoring. Sensors are also deployed to monitor flow, volume and carrying capacities of rivers while rain gauges capture precipitation volumes. These data may be complemented with census data on population and livelihoods of residents. All these various data are kept in the Database component of the DSS.

The second component of the FDSS are functions of analytics and modelling. Various analysis are carried out and the data in the database taking through several processes of manipulation. These processes of data manipulation and analysis differ in approach and are tailored to meet various goals in the decision making process. Prominent among the tools used at this stage is Geographic Information Systems (GIS) tools. Regarding flood modelling, advanced tools available to flood managers include advanced technological tools in soft computing, for instance, evolutionary computing, as well as probabilistic predictions techniques of inundation recurrence intervals [41]. These tools afford flood managers varieties of techniques that can be applied in simulation, modelling, analysis and management of flood.

The User Interface component of the FDSS provides flood decision makers an interactive graphical interface, enabling users to query the data stored in the system. It again enable users to display and visualise the models and reports from the manipulations of the data. This component of the advanced FDSS enables users to prepare and appreciate maps and animations of the hydrologic phenomena being studied.

6.1 Remote sensing and geographic information systems in disaster management

Advances in remote sensing tools and techniques over the past few years have provided disaster managers, especially flood disaster managers with powerful tools in the acquisition of flood sense data, in forecasting and monitoring of flood occurrences and in the management of watersheds, rivers and wetland areas.

Remote sensing refers to the Science of obtaining information about objects, areas or phenomena from a distance [42]. Typically, these information are collected through sensors that are planted on aircrafts or satellites. In flood disaster management, remote sensing can be applied to monitor and map events such as changes

in river volume, changes in coastline, map wetlands and flood prone zones and boundaries of inundation.

A Geographic Information System(s) (GISs) refers to a framework for gathering, managing and analysing location-based data. This framework is used to analyse and organize several distinct layers of location-based information into concise visualizations through maps and 3D scenes. Ultimately, GISs present powerful capabilities that proffer deeper insights into data, which may include revelation of patterns and relationships for smarter decision making [43].

Reliable flood maps are therefore produced using GIS techniques and remotely sensed data to manage floods. GIS tools aid in the preparations to Digital Elevation Models (DEMs) for high level hydrological modelling using sensors such as The Light Detecting and Ranging (LiDAR) sensors.

With the help of data interpretation techniques of GIS, remotely-sensed imageries are interpreted to create suitable flood risk mitigation frameworks and FDSSs. Although flood disasters have increased in scale and frequency in recent years, there has been a commensurate improvement in flood data capturing and analyses techniques, that when applied in time, can significantly mitigate the risks and impacts of floods. As summarised in **Table 1**, GIS and RS are of great importance in the pre and post disaster management processes.

6.2 Internet of Things (IoT) and Big Data in flood disaster management

The Internet of Things (IoT) refers to a network of devices connected over the internet to sense, track and respond to issues. Patel and Patel [45] defines the IoT as "*a type of network to connect anything with the internet based on stipulated protocols through information sensing equipment to conduct information exchange and communications in order to achieve smart recognitions, positioning, tracing, monitoring and administration.*"

The network of physical objects are able collect data on a regular bases and in a structured form, perform high level analysis and predict changes, as well as initiate actions based on results from the analyses. IoT is hence a powerful technological tool that can provide a wealth of high level intelligence which is needed in planning and management.

There are three levels of IoT. The first is people to people interconnectivity, the second is people to machine interconnectivity and the third being machine to

Phases in Flood Disaster Management	*Relevance of GIS and RS*
Flood Prevention	Capturing imageries for hazards and risks assessment. Preparation of flood prone maps. Management of large volume of flood sense data.
Flood preparedness	As tools for planning evacuation routes. Designing centers for emergency operations. Integrating and Simulating live satellite data with other dataset to inform early warning systems.
Flood relief	Planning and execution of search and rescue operations. Planning distribution of relief items to flood victims
Flood rehabilitation	Flood impact assessment. Rehabilitation planning.

Table 1.
Showing GIS and Remote Sensing Application in flood disaster management. Source: Authors' Construct with reference to [44].

machine or things to things interconnectivity [45]. In all interconnectivity of things and people, the internet remains the main driver. This interconnectivity of Things, enables the swift transmission of meteorological, hydrological and geological data pertaining to flood events.

In flood disaster management, providing a quick feedback on the occurrence of floods can be a great step in preventing and mitigating flood disasters and their impact on livelihoods in society. Deploying IoT in flood management puts disaster managers at a position to create enhanced early warning systems that do not only measure the water levels and the speed of inundation, but early warning systems that could also send alerts to residents and flood managers through mobile phones and other personal electronic devices, and additionally, prescribe the best prevention and mitigation strategies based on data such as direction of runoff, speed of rise of water levels and the time at the disposal of residents to take necessary action.

Big Data on the other hand, refers to "*the evolution and use of technologies that provide the right user at the right time with the right information from a mass of data that has been growing exponentially for a long time in our society*" [46]. Digital data collection has not only seen growth in volume but also in variety in storage formats, hence Big Data is often described as high-volume, high-velocity and/or high variety information assets that demand cost-effective, innovative forms of information processing to enable enhanced insight, decision making and process automation [47].

Big data typically defines data that exceeds the storage, processing and computing capacity of conventional database [46]. Hence Big Data analytics typically involves automated software that assist in the collection, organisation and analysis of the data being generated to discover trends, correlations and other useful results to prompt necessary action.

Through Big data process automation, precipitation data, soil moisture data, temperature data, water content data of water bodies, data on evapotranspiration, ground water data, etc., are collected and processed in real-time without human supervision to make predictions and early warnings about flood disasters' occurrence [47].

7. Conclusion

Flood disasters have had very devastating impacts on societies and have destroyed livelihoods and investments of staggering monetary value and importance to development. However, adequate involvement of technology are leading to the creation of people-centered early warning systems that enhances residents' awareness and preparedness to flood events to significantly reduce the adverse impacts of these disasters on people. This chapter discussed various aspects of flood disaster management including early warning systems, flood mitigation and adaptation strategies, the relevance of monitoring, evaluation and mainstreaming flood disaster management into national level development planning. The chapter again discussed and encourage the integration of advanced technological tools into the frontier of flood disaster management, as these tools have the capacity to capture, analyse and disseminate real-time flood data to all stakeholders to safeguard lives and precious investments.

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