The Economic Impacts of Climate Change in Kenya: Riparian Flood Impacts and Cost of Adaptation

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Aim and Scope of Study

The overall aim of this case study is to assess the physical and economic impacts of climate change with a focus on riparian floods and estimated cost of adapting to the present and future flood risk in Kenya. The study seeks to quantity the economic cost of actual impacts and the losses accrued from the deviation from likely economic activity as a result of specific flood events in the last two decades. The 1997/98 El Niño and the 2006 flood events associated with widespread impacts across the country are considered. The geographical focus of the study is the Budalang'i and Kano flood plains in Lake Victoria Basin (LVB) in western Kenya and Tana River flood plains in the southeastern part of the country.

Study Area

The study focuses on the Lake Victoria Basin and lower Tana River Basin in western and southeastern part of the country.

The Lake Victoria Basin (LVB)

The Lake Victoria Basin has a total catchment area of 194,00km^2 shared between the five Eastern African countries of Burundi, Kenya, Rwanda, Tanzania and Uganda. The catchment area of the Lake found in Kenya has an area of 46,229km^2 and receives part of its inflow from Rivers Sio, Nzoia, Yala, Nyando and Sondu that rise from the Western Highlands[1]. River Nzoia extends to 334km up to its outfall into the Lake and has the largest catchment area of 12, 709km^2. Rivers Nzoia and Nyando experience extensive floods in their lower reaches affecting the Budalangi and Kano flood plains[2]. Other districts affected by floods in western Kenya include; Busia, Budalangi, Kisumu, Nyando, Bondo, Migori and Siaya. Kisumu is the largest town in the basin with a population of one million. Approximately 65% of the land in western Kenya is arable land supporting both food and cash crops and livestock farming. Fishing is the main form of livelihood in the region but agriculture is most dominant due to the good rains received in the region. The average annual rainfall in the basin is 1,424 mm and varies between 891mm in parts of the Mara catchment to a maximum of 2,168 mm in the middle reaches of Yala basin.

The Tana River Basin

The Tana River Basin is one of the biggest river basins in Kenya. The study focus on the middle and lower parts of Tana River basin that are prone to recurrent floods; mainly Tana River and Garissa districts. Tana River district has a total area of 38,694km^2 while Garissa is 43,931km^2. The River stretches to a length of 1,00okm and has a drainage area

[1] Western Highlands comprise of Cherangani Hills, Nandi Hills and Mt Elgon and are the sources of major rivers in western Kenya.

[2] 13,000 ha out of the 73,000 ha of the Kano Plains is swampy and prone to flooding of River Nyando. (WMO and GoK, 2004).

of approximately 126,000km$^{2.}$ It runs from the Central Highlands[3] of Kenya through the arid and semi arid lands in the eastern part of the country and into the Indian Ocean. Tana River supports the livelihoods of more than four million most of whom are pastoralist, farmers and fisherfolks.

1.0 Introduction and Background

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) notes that a warmer climate coupled with increased climate variability such as El Niño will significantly increase the risk of floods in poor countries in the developing world (IPCC, 2007). Current climate variability is believed to be having a significant influence on the frequency and magnitude of climatic related disasters like floods and droughts. Climatic related disasters constitute over 70% of all disasters in Kenya.

Floods are the leading hydro-meteorological disaster in East Africa[4]. In Kenya, floods are emerging as the most prevalent climatic disaster (RoK, 2007; ISDR). Perennial floods affect low-lying regions of the country such as river valleys, swampy areas, lakeshores and the coastal strip that are unevenly distributed in the country's five drainage basins (Figure 1). Geographically, the western, northern, eastern, central and south-eastern parts of the country are quite susceptible to seasonal floods in the wet seasons of March-April-May (MAM) and October-November-December (OND). The Lake Victoria Basin in western Kenya (Figure 2) is the most flood-prone region in the country (RoK, 2007). The Arid and Semi Arid Lands (ASALs) that comprise of 80% of total landmass in Kenya are also prone to floods. This is despite of the fact that ASAL districts such as Garissa and Tana River record an average rainfall of only 300-500mm annually compared to the rainfall received in the Western and Central Highlands[5] that receive an annual rainfall of between 1600-2000mm (WRI et al., 2007)

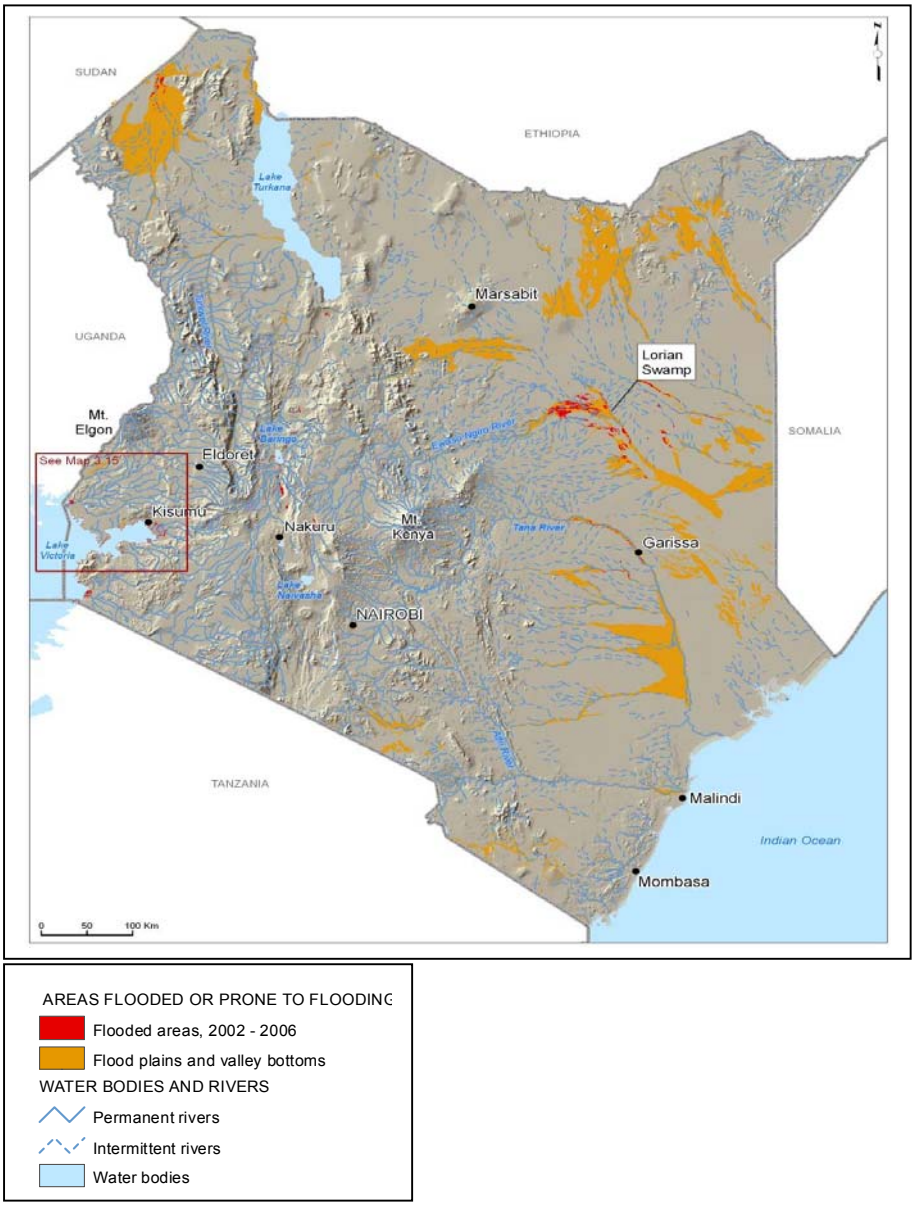
Western Kenya is characteristically wet through out the year with no distinctive dry season. High rainfall is received in the months of March to September, with significantly lower rainfall in January and February (SoK, 2003 in WRI et al., 2007). Contrary to the bimodal rainfall pattern in the rest of the country, a third rainfall season is experienced during the cold and dry months of June-July-August (JJA). (ICPAC, 2007). The mean annual rainfall in western Kenya is above 1600 mm (WRI et al., 2007).

The high vulnerability to flood risk in western Kenya is as a result of high poverty rates, poor land use patterns (deforestation and settling and cultivating along river banks), low education and illiteracy levels and the state of infrastructure that is in neglect.

The prevalence rates of floods in Kenya stands at 27% and affects 5% of the population affected by disasters. Floods related fatalities constitute a whooping 60% of disaster victims in Kenya (UNEP, 2009). Flood occurrence trends in western Kenya is increasingly becoming a major concern to the country's socio-economic development due to the substantial economic and financial losses incurred to respond to frequent flood disasters.

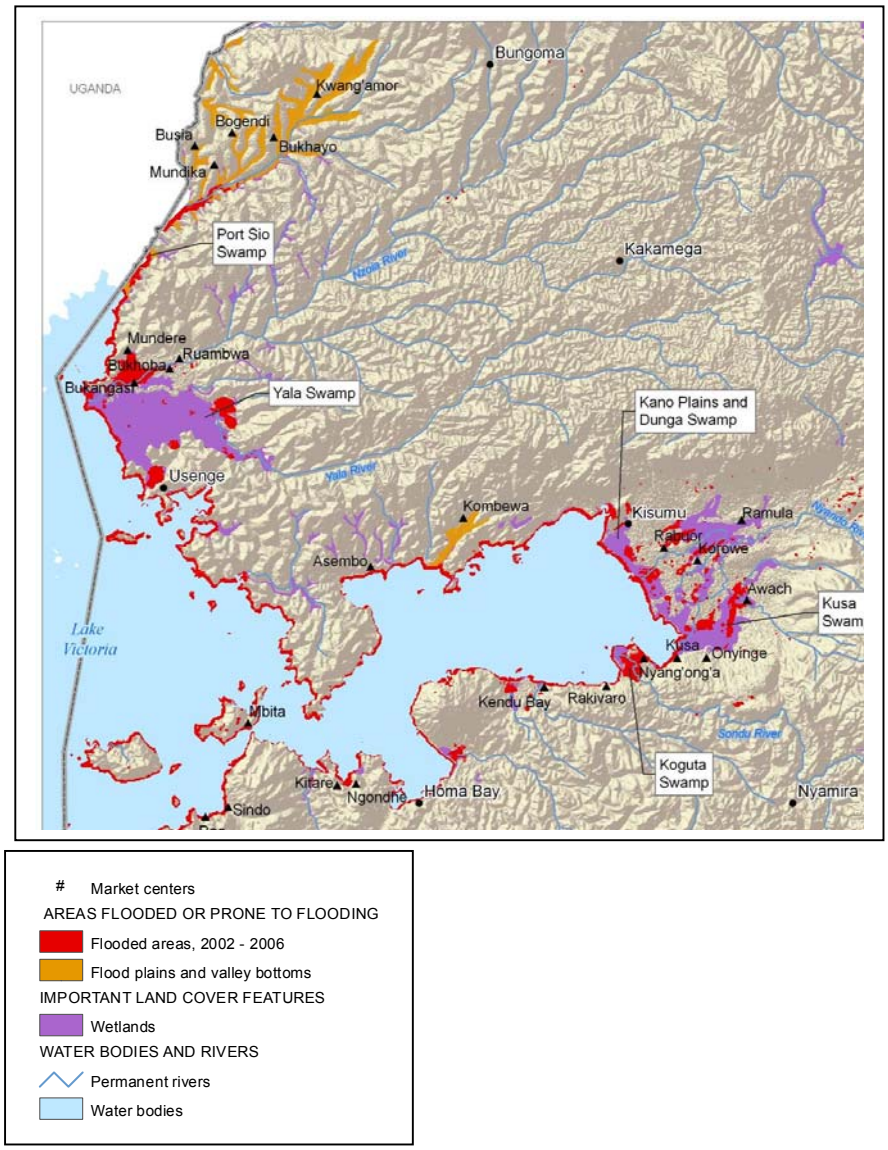
[3] Central Highlands comprise of Mt Kenya and Aberdare Ranges, the source of River Tana
[4] 2008 data from the Centre for Research in Epidemiology of Disasters (CRED)
[5] Central Highlands comprise of Mt Kenya and Abardare Ranges and are the sources of floods on River Tana.

Figure 1: Kenya's Flood Prone Regions



Map floodplain in Kenya: areas in red indicate regions inundated between 2002-2006- Source: World Resource Institute, 2007

Figure 2: Flood Prone Regions of Lake Victoria Basin in Western Kenya



Map showing areas inundated areas around the shores of Lake Victoria Basin in the period 2002-2006-- Source: World Resource Institute, 2006

1.1 Characterization of Present Flood Risks

Rainfall is the most important climatic variable in Kenya that supports most livelihoods, including rain-fed agriculture. An annual rainfall pattern in the country indicates high spatial and temporal variations with a strong bimodal seasonal trend across the country. The months of March-April-May (MAM) and October-November-December (OND) record the highest rainfall peaks. The two rainfall seasons are commonly referred to as the "long" and "short" rains respectively. Torrential rainfall experienced during the wet months often translates into high stream/river flow (runoff) in permanent and intermittent streams/rivers across the country resulting to seasonal floods. (Osbahr and Viner 2006; WRI et al., 2007) indicate that rainfall seasons can be extremely wet and erratic resulting to both large and small river devastating floods like the El Niño floods of 1997/98 with significant socio-economic impacts.

Flood producing rains in Kenya are often driven by complex climatic variability phenomenon such as the El Niño Southern Oscillation (ENSO)[6] and tropical storms. Ogallo (1988; 1989, 1993) cited in ICPAC (2007) notes that specific floods in Kenya have been associated with El Niño. Kenya was amongst the 16 worst affected tropical and Pacific Rim countries during the 1997/98 El Niño (Gadain et al., 2006, Glantz, 2001) .The 1997-98 El Niño floods of the century as they have become to known resulted in severe floods after major rivers in the country attained record peaks leading to widespread riparian floods costly impacts. Kenya is one of the countries in the Greater Horn of Africa (GHA) region that has been identified as having a strong ENSO signal (El Niño and La Nina). The warm and cold ENSO cycles are often, but not always associated with above/below average rainfall amounts that lead to floods and droughts respectively. El Niño is already a major concern to Kenya due to its adverse impacts including floods and droughts (R.o.K, 2002).

Riverine floods are the most dominant floods in Kenya. River floods mostly occur along floodplains or wash lands as a result of exceeded stream flow capacity leading to over spilling of the natural banks or artificial embankments (Smith and Ward, 1998). Riverine floods include extreme events like the El Niño flood of 1997-98 with a low flood probability[7] of 35-40 years (Q_{35-40}) and the more frequent small floods with a high flood probability of up to five years (Q_5). Major rivers in the country such as Nzoia, Nyando, Yala, Athi, Nairobi and Tana experience seasonal river floods emanating from the country's highlands that receive high annual rainfall ranging from 1600-2000mm. These rivers flooded during the 1997/98 floods.

River floods affect both the rural and urban areas in form of flash and urban floods. Flash floods have a characteristic short duration and steep rises and rapid falls of flood levels. They occur abruptly without much warning as a result of an accelerated runoff or sudden dam failure and are quite destructive due to their sudden occurrence. The arid and semi arid lands of Kenya and urban areas are particularly vulnerable to flash/sheet flooding.

Urban floods result from over spilling or surface ponding or when urban storm water drains become surcharged and over flow (Smith and Ward, 1998). Urban floods are common in major cities and towns in Kenya including Nairobi, Mombasa, Kisumu, Nakuru, and Garissa. Many of these urban areas experienced floods during the El Niño rains of 1997-98. The cause of urban floods in Kenya is mainly poorly maintained drainage systems. Urban floods mainly affect residents of informal settlements (slums) mushrooming in the country's major cities. (ICPAC, 2007; UN/OCHA, 2006). The second largest city of Mombasa experienced severe flooding in October 2006 that affected 60,000 people in the city and coastal region (Awuor et al; 2008). The most recent urban floods occurred in Kisumu city between 20-21 September 2009 leaving 150 families displaced and 4 feared dead. This flood was linked to El Niño rains that were forecasted by the Kenya Meteorological Department (KMD) during the short rain season of 2009.

[6] El Niño is a complex interaction of the tropical Pacific Ocean and the global atmosphere that results in irregular episodes of changed sea surface temperatures accompanied by either above or below average rainfall in the tropics and Pacific Rim countries (ISDR, 2004).

[7] Flood frequency/probability is the statistical measure of the likely occurrence of a flood of a given magnitude (Smith and Ward, 1998)

1.2 Quantified Physical and Economic Impacts of Past Flood Events

Flood impacts in Kenya can be broadly categorised into two; flood damages and flood losses. Flood damages include physical destruction (direct and tangible losses[8]) to public and private assets such infrastructure, houses, buildings, crops and vehicles resultant from contact of the assets with floodwater. Flood loss is a much broader term encompassing secondary and tertiary losses as well as intangible losses[9] such as human and livestock life, health and associated fatalities from drowning or flood-related diseases. A comprehensive assessment of economic impacts of floods must take into consideration both the direct and tangible impacts (flood damages) as well as indirect and intangible impacts (flood losses).

Floods impacts in Kenya are felt across various sectors of the economy including: agriculture, livestock, transport, housing, public health, industrial processing, and tourism. The impacts have severe socio-economic and political implications.

Economic impact

An initial scoping study on the economic impacts of climate change in Kenya estimated that extreme floods and drought events have the potential to reduce the country's GDP by about 2.4% per annum. In the last three decades, flood losses in Kenya have been increasing tremendously as compared to drought losses. Figure 3 indicates the high the cost of floods in the country between 1964 and 2004. The 1997/98 El Niño flood was associated with one of the largest flood losses in the country in 50 years (Mogaka, et al; 2006). The economic and financial losses associated with the El Niño flood is in the range of up to US$800 million (Karanja et al., 2001). The World Bank estimated the cost of the flood at Ksh 70 billion equivalent to US$ 1 billion[10].

Flood assessment studies recently undertaken along the last 20 km reach of the Nzoia River in western Kenya indicate that annual flood damages amount to about US$4.8 million in the Budalang'i floodplains. The average annual flood damages in the Kano Plains is about US$ 850,000 (Eitel and Ochola, 2006). During the flood of 2003, the ASAL district of Garissa incurred flood losses of over Ksh.500 million following a flash flood according to the Arid Lands Resource Management Project (ALRMP).

[8] Tangible impacts include losses of things that have a monetary value and can be replaced at a cost for example, buildings, livestock and infrastructure

[9] Intangible impacts refers to the losses of things without a monetary value for example, lives and injuries, heritage items, memorabilia

[10] Estimates costs available from the Economic Impacts of Climate Change in Kenya initial project idea note

Figure 3: Cost of Damages from Climatic Related Disasters in Kenya

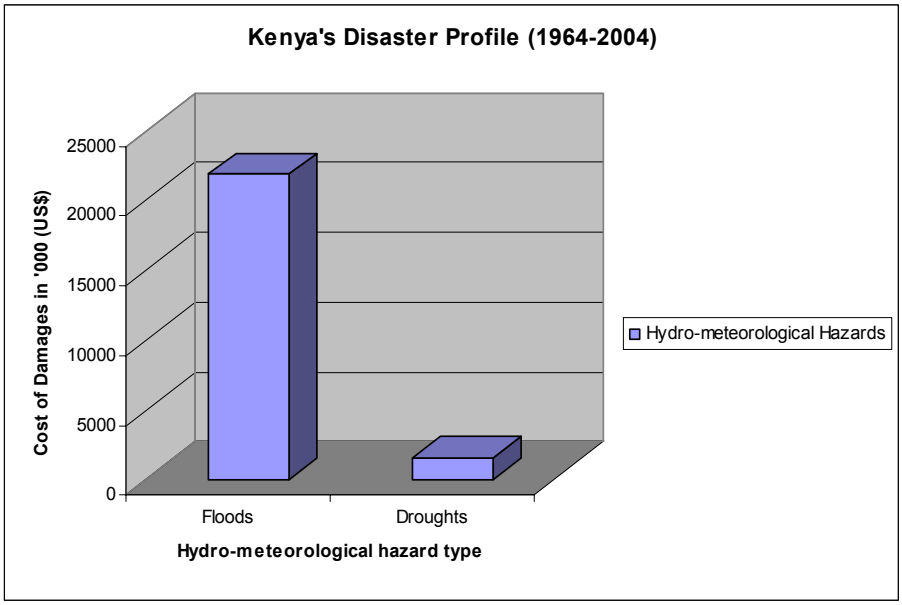


Figure showing increasing economic costs accruing from floods as compared to droughts in Kenya.
Source: ISDR (EM-DAT Statistics)

Human Displacement and Destruction of Business Premises

Thousands of people in the country's flood-prone areas are displaced and rendered homeless following destruction of their homes leading to internally displaced persons. Buildings and business premises are also affected during floods. Table 1 summarises the numbers of flood victims; displaced persons and fatalities in Kenya in the last decade. The worst affected settlements and businesses are those developed in low-lying lands in rural and urban areas of the country including the lakeside city of Kisumu and coastal city of Mombasa. The most vulnerable people are the poor who are forced to settle in risk floodplains to eke out a living from agriculture, livestock farming and fisheries.

Figure 4: Impacts of Floods on Human Settlements

(a) Photos of displaced residents in a slum area (b) Submerged hut in western Kenya
Source: GoK, 2006

Table 1: Number of People Affected by Recent Floods in Kenya in the last Decade

Year	Region Affected (Provinces)	No of People Affected	
		Displaced	Fatalities
2009	Nyanza (Kisumu town)	150 families	5
2008	Nyanza, Northeastern, Rift Valley, Coastal	12,000	5
2007	Western, Nyanza	20,610	9
2006	Nyanza, Western, Coast and Eastern	723,000	66
2005	Western, Nyanza, Eastern, Northeastern	35,000 including 25,000 refugees in Daadab	20
2004	Widespread	2,500	50
2003	Western, Eastern,	1,000,000	77
2002	Western, Nyanza, Eastern, Coastal	150,000	14
2001	Nairobi	Missing data	4
1997-98	Widespread	1,500,000*	53

Table showing regions and flood victims from recent floods in Kenya
*Figure includes people affected in 4 East and Horn of Africa Countries including Kenya, Somalia, Ethiopia and Tanzania including over 2000 deaths

Source: Government of Kenya (2007) and Dartmouth Flood Observatory (DFO), September 22, The Standard Newspaper

Figure 5: Impacts of Floods on Port Business at the Port of Mombasa

Photos of flooded cargo containers at the port of Mombasa
Adapted from Awuor et al; 2007

Public Health and Sanitation

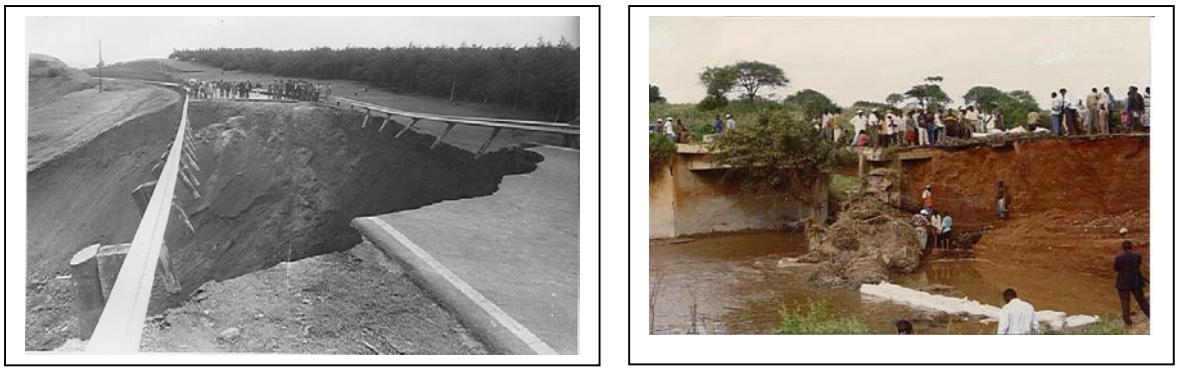
Floods result in the destruction of water and sanitation infrastructure. This has negative impacts on public health as a result of coming into contact with contaminated water that increases the prevalence of water-related diseases such as malaria, cholera, diarrhoea and typhoid. The 2006 floods were associated with one of the highest human deaths from malaria and rift valley fever epidemic following the 1997/98 El Niño flood (ICPAC, 2007; Osbahr and Viner, 2006). There was an overstretching of health resources as a result of over 3 million families suffering from poor health after the 1997/98 El Niño floods in Kenya. Bovine disease was responsible for an 80% reduction of livestock in northern Kenya according to a WHO report on the health impacts of the El Niño flood of 1997/98.

Infrastructure Damage

Major infrastructure that supports national economy such as roads, bridges and water piplines are prone to damages as result of floods. The 1997/98 El Niño floods seriously damaged water supply infrastructure and transport networks across the country. Dams, water pans, and some pipelines in 22 districts were either destroyed or severely damaged (Mogaka et al; 2006). Table 2 summarises flood damage costs in the water sector.

Extensive damage was also caused to 240 river gauging facilities due to severe bank erosion. The protective dykes were over topped and suffered breaches at several places. The floods also damaged irrigation infrastructure such as intake structures, canals and drains. The Perkerra River changed its course, depriving the Perkerra Irrigation Scheme of water for some years (Mogaka et al; 2006).

Figure 6: Impacts of Floods on Transport Infrastructure



(a) Photos of a destroyed road and (b) bridge following floods in Kenya

The October 2006 floods in Kenya caused damages to major roads in the country. A 5km section of the main Bura and Garissa-Dadaab roads was completely cut off resulting in the isolation of communities for extend periods and disruption of transport, communication and business activities. The knock-on effects include shortages of food and other basic supplies across the country. Relief operations coordinated by the government and other relief and humanitarian agencies during the flood disaster were also affected due to destruction of transport infrastructure.

Table 2: Flood Damage Costs in the Water Sector after the 1997/98 El Niño floods in Kenya

District	Type of Service Affected	Cost (Million of Kshs)
Wajir	Dams, pans silted up	95
Garissa	Dams, pans silted up	114
Mandera	Dams, pans silted up	63
Lamu	Dams, pans silted up, water pipeline destroyed	48
Malindi	Dams, pans silted up, water pipeline destroyed	16
Taita Taveta	Dams, pans silted up	9
Kilifi	Dams, pans silted up	26
Tana River	Dams, pans damaged	63
Kwale	Dams, pans silted up, water pipeline destroyed	58
Kisumu	Dams, pans silted up, water pipeline destroyed	11
Suba	Dams, pans silted up, water pipeline destroyed	19
Rachuonyo	Dams, pans silted up, water pipeline destroyed	9
Busia	Dams, pans silted up, water pipeline destroyed	63
Isiolo	Earth dams/pans destroyed	42
Makueni	Earth dams/pans destroyed	34
Mwingi	Earth dams/pans destroyed	11
Moyale	Dams, pans silted up, water pipeline destroyed	29
Marsabit	Earth dams/pans destroyed	29
Baringo	Dams, pans silted up, water distribution network damaged	134
Keiyo	Earth dams/pans destroyed	16
Marakwet	Dams, pans silted up, water pipeline destroyed	11
Ssamburu	Dams, pans silted up, water pipeline destroyed	26
National Water Conservation and Pipeline Corporation		
Kwale		28
Kilifi		220
Total (22 Districts and some NWCPC)		**1,200**

Adapted from Climate Variability and Water Resources Degradation in Kenya: Improving Water Resource Development and Management (World Bank, 2006)

Livelihoods

The impact of floods on populations differs depending on the livelihood and wealth group of the community. In Kenya, agriculture and livestock production are the main sources of livelihoods and are severely affected by floods. According to a livelihood zoning exercise undertaken by World Bank in 30 districts in the country following the 1997/98 El Niño, most sources of livelihoods in Tana River and Garissa districts- fishing, subsistence cropping, urban and pastoralism, dry riverine, and agro-pastoralism were

negatively affected. This resulted in the livelihoods of approximately one million people in Tana River district depending on the River's flooding regime for agriculture at high risk.

The destruction of irrigation infrastructure has an impact on the livelihoods of those dependent on irrigated agriculture. Herds of livestock died from drowning in the floodwaters during the El Niño flood of 1997/98. Pastoralists suffered from reduced incomes of which 68% is derived from livestock. Figure 7a shows the number of livestock before and after the floods. This resulted in the complete collapse of the main source of income amongst the pastoralists and agro-pastoralists. In addition to direct loss of animals, the decrease in livestock marketability also affected income generation. Food consumption was also affected due to the decreased production of milk and meat from livestock. The loss of income also translated into loss purchasing power. The combination of low purchasing power and high food commodity prices worsened the situation.

Agriculture

Floods result in the inundation of productive agricultural land leading to destruction of crops. This has an impact on agricultural productivity leading to food security in the areas directly affected and those that produce food consumed in other parts of the country. Floodwaters may also destroy harvested food that has been stored.

Farming communities in Budalang'i, Kano Plains and the lower Tana River Basin are displaced every year. In Budalang'i, there is over 50 percent reduction in agricultural production once every three years. The Kano Plains was almost fully inundated and agricultural crops were completely destroyed during the El Niño Floods in 1997/98. It is estimated that 200 acres of crops along the banks of Tana River in the Coastal province were destroyed during the floods (Osbahr and Viner, 2006). About 1,200 hectares of bananas, tomatoes, and vegetables were reportedly washed away in Garissa district. In Tana River district, 100% of bananas, mangoes, rice, maize and pulses were destroyed (Gadain et al; 2006). The destruction of crops resulted in drastic increase in commodity prices as indicated in Figure 7b. The food shortage had a major effect on the health of children under five years old. This was evident by the prevalence of delayed malnutrition disorders such as kwashiorkor and marasmus. Tana River, Garissa and Lamu districts recorded cases of marasmus that soared for several months after the flood (Mogaka et al; 2006).

Environmental

In addition to physical impacts on build environment, floods have a negative impact on the natural environment as well. The El Niño floods resulted to land degradation and increased soil erosion with consequent silting of hydropower dams. A weir on Kipchoria River, a tributary of the Nyando, was washed away and a water supply dam in Kericho district was silted up.

Ecological damage has negative impacts on the tourism industry in Kenya. Coral reefs, a major attraction of tourists in the coastal town of Mombasa were damaged from sediment deposits, and coral production was inhibited by lack of light. More than 50 percent of the coral reefs in Malindi were killed as a result of the 1997/98 El Niño floods. There was also a significant reduction in light penetration around the discharge points of the rivers, and the waters became eutrophied and deoxygenated.

Disaster Risk Management Responses

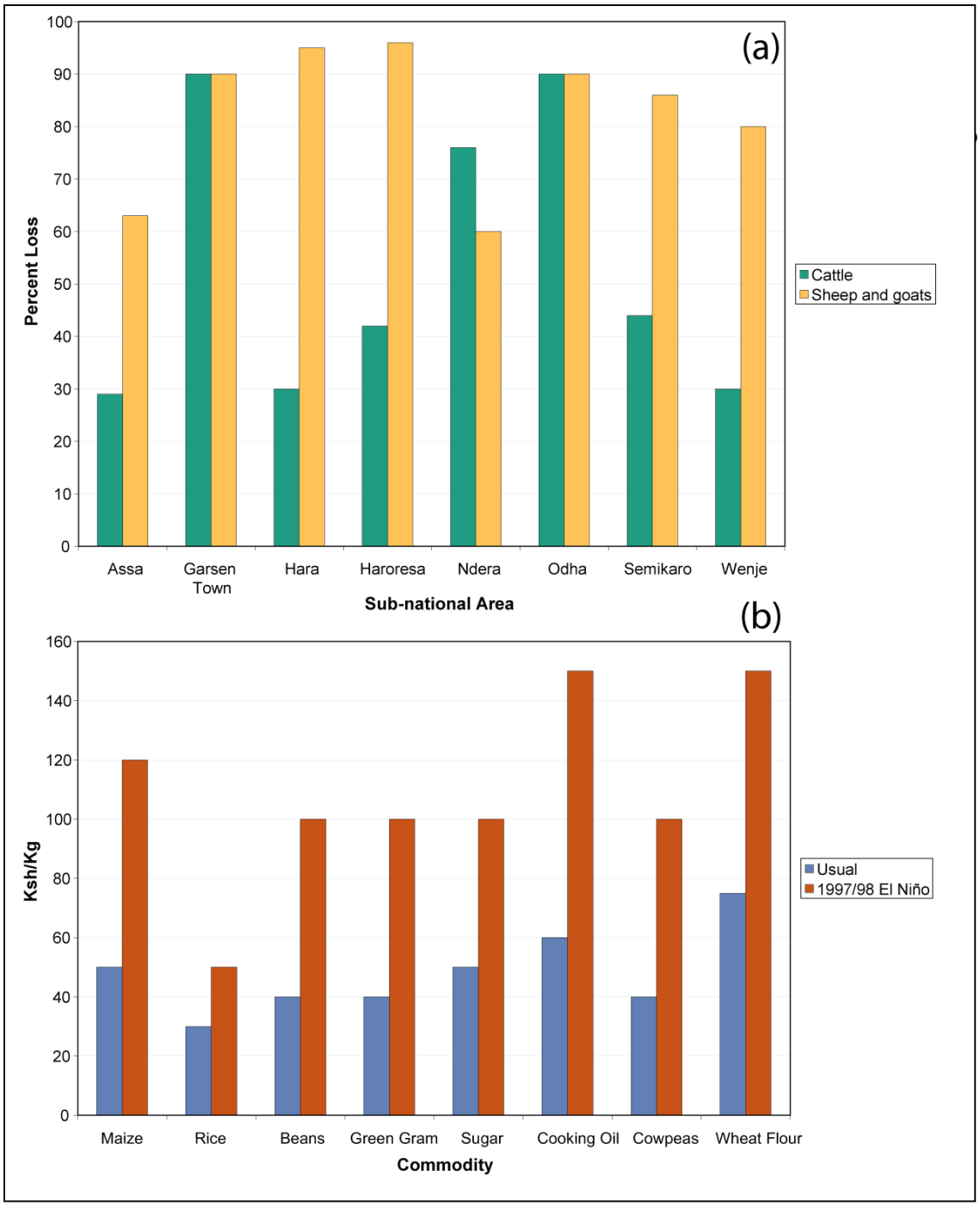
Humanitarian assistance undertaken as part of short-term disaster risk reduction measures geared to alleviate immediate suffering of disaster victims is negatively affected during floods. The cost transporting food and non-food items to affected communities is greatly increased due to transportation of relief items using more expensive means such as air following destruction of roads and bridges in flood affected remote regions of the country. During the 1997-98 El Niño floods roads in Tana River and Garissa districts were either severely damaged, gullied or silted becoming completely impassable. This resulted in some affected communities being completely isolated with no means receive humanitarian assistance with ease.

Table 3: Relief Beneficiaries in Nzoia and Nyando sub-basins of Western Kenya during the 2006 Flood

Catchments	Affected			Relief Beneficiaries	
	Districts	Population Affected	Displaced	Persons	Households
Nzoia	Budalang'i	15,888	2,648	13,560	2,260
Nyando	Nyando	6,720	1,120	3,360	560
Total		**22,608**	**3,768**	**16,920**	**2,820**

Table showing the number of people affected at district and household level during the recent flooding of 2006
Source of data: Kenya Red Cross Society (2007)

Figure 7: Impacts of floods on market prices: (a) food commodity prices (b) livestock losses



Adopted from Gadain et al; 2006
Source of data: UNICEF, 1998

1.5. Future Development Plans for Riparian Areas

Floodplains have multiple socio-economic benefits that attract settlements. The fertile alluvial soils found on flood plains for example are ideal for high crop production, livestock farming. The current investment in flood management infrastructure is flawed since it is largely based on humanitarian considerations that are short term in nature. Future development of riparian areas must be considered from this backdrop and forward looking development planning be considered with the view of providing long-term infrastructure that can support the economic potential of such areas such as planned and flood proofed settlements and transport infrastructure.

According to a study by the Ministry of Housing, the land carrying capacity[11] of most districts in LVB is almost exceeded due to population increase. Future sustainable development planning for riparian areas also needs to consider the issue of rural population. Overpopulation results would result in fragmentation of land holdings leading to higher levels of flood risk as people invade floodplains due to land and population pressure. Rural overpopulation is currently one of the main factors of the high flood risk to riverine communities in the region. Appropriate policies to facilitate planned urbanization and creation of gainful employment opportunities to the increasing population could help reduce flood risk in the region.

The theme of District Development Plans for the period 2002-08 for 27 districts was "effective management for sustainable economic growth and poverty reduction". The plans had moderate development objectives anchored at reducing extreme poverty in the country including flood-prone districts in western Kenya. The emphasis was on improving the physical and social infrastructure including transport network and housing schemes within the prevailing resource constraints. Industrial development that supports urbanization was envisaged to compliment rain-fed agriculture that is highly vulnerable to floods. The focus of urban development plans for the period 2002-08 focussed on schemes to restore and rehabilitate infrastructure. Integrated Water Resource Management that includes flood risk management should be considered as a critical component of developmental strategy for the both rural and urban areas in riparian areas.

1.6. Increased Vulnerabilities to Future Development Plans

Floodplains in western Kenya are bound to attract large populations in future given their multiple benefits and population pressure. Western Kenya is high populated and a sudden rise of the number of people inhabiting floodplains would increase those that becoming vulnerable to floods due to over crowding in the risky areas. Considering the land carrying capacity, the growth of rural population and poor state of existing infrastructure, future development planning must focus on various strategies cutting across key economic sectors and forms of livelihoods in the region.

[11] Land carrying capacity is calculated assuming the full development of agricultural potential (WMO and GoK, 2004)

2.0 Cost of Adaptation: Flood Risk Reduction

The cost of adapting to climate change is increasingly gaining relevance in the agenda of researchers, policymakers, and programme developers and implementers who are aware that climate change is a real threat to social, ecological and economic sustainability in many developing countries like Kenya. In all sectors of the economy affected by flood, adaptation efforts focus on implementing flood risk reduction measures that help build rural and urban livelihoods that are more resilient to climate variability and associated climatic disasters such as floods.

2.1 Projects and Programme Based Measures

The Western Kenya Community Driven Development and Flood Mitigation Project (WKCDD/FM)

The Ministry of State for Special Programmes is currently implementing the Western Kenya Community Driven Development and Flood Mitigation Project (WKCDD/FMP) for Special Programmes through the Flood Management Unit established in July 2007. One of the objectives of this World Bank funded project is to reduce the financial cost induced by average annual flooding in the Budalang'i flood plain. This includes the cost of damages to property, agricultural activities and resettlement of displaced communities. At the moment, the government of Kenya has earmarked a total of Ksh 40million for the rehabilitation of dykes in Budalang'i that are breached by annual seasonal floods. This is in anticipation of the El Niño short rains expected during the October-December rains. The project design includes a portfolio of projects designed to deliver flood mitigation and improve livelihoods at grassroots level among the most vulnerable and poor communities exposed to flood risk on an annual basis. The community development aspect of the project feeds into the government's commitment in delivering flood risk management within the tenets of sustainable development.

The flood mitigation component of the project that focuses on the Nzoia and Yala basins will address the following issues; catchment management to address degradation; the identification and preparation of options for mid-catchment structural protection (multi-purpose storage and attenuation structures); options for immediate floodplain management; and the establishment of a community based flood early warning system. The flood early warning system will be designed to link international and national information systems with local communities.

Table 4: Costs of Specific components of the Western Kenya Community Driven and Flood Mitigation Project in Kenya

Project Focus	Cost in Millions of US$	
	Total Funding	International Development Assistance (IDA)
Catchment management	20.7	19.6
Flood mitigation	35.6	32.9
Multipurpose flood management	4.7	4.7
Floodplain management	6.7	5.4
Flood early warning system	5.5	3.2

Dykes

Dykes are found along the vast network of permanent rivers in Lake Victoria Basin that experience seasonal flooding. The dykes on River Nzoia measure 36.4 km in length with 16.2 km in the northern and 18.4 km on the southern banks of the River. They offer protection to residents in Busia and Budalang'i districts in western Kenya (GoK, 2007). The construction of River Nzoia dykes began in 1977 and was completed in 1984 at a cost of Ksh 17 million (WMO and GoK, 2004).

River Nyando has low dykes measuring 1 metre high. These were erected by the local community with assistance from the local administrative units. Check dams and diversion channels have been built by the Ministry of Agriculture to offer protection to agricultural fields along River Nyando's flood plain. Only 8 km of dykes, 4 km on either banks were in place in the lower reaches of River Nyando by the year 2004. (WMO and GoK, 2004). This was part of a major government project to design and construct flood protection structures along River Nyando in 1984. The first phase was to deliver 16km of dykes on the left and right banks. Phase II was to extend the dyke to a distance of 18km upstream to offer more protection. Phase III envisaged a multipurpose schemes comprising of check dams, canals for irrigation and hydropower and flood control dams (WMO and GoK, 2004).

Multipurpose Reservoirs

The Seven Forks Dam project consists of a series of multipurpose reservoirs in the upper catchment of Tana River. In addition to serving as flood control measures, the dams were developed as part of the hydropower scheme and for irrigation use. The first dam, Kindaruma was completed in 1968 followed by Kamburu (1975), Gitaru (1978) and Masinga (1981) and Kiambere in 1981.

Radio Internet Project (RANET) for Dissemination of Information to Rural communities

The Radio and Internet (RANET) programme offers an opportunity for disseminating flood forecasts to vulnerable rural communities in the flood prone areas of Kenya. RANET is an initiative of the African Meteorological Applications for Development (ACMAD) and National Hydrological and Meteorological Services (NHMS) in different countries. The programme was introduced in Kenya by the Kenya Meteorological Department (KMD) in 2001. Currently, there are 15 RANET information stations established in the country. Western Kenya hosts three centres in Kisumu, Kakamega and Eldoret. The process of setting up a centre in the flood prone Budalang'i district is currently underway according to the government of Kenya (RoK, 2006).

Emergency Relief and Rehabilitation

The government coordinates flood emergency, relief and rehabilitation response measures through the Rapid-Onset Disaster Committee and District Steering Committees. Humanitarian activities are undertaken in the affected districts with support from other agencies involved in humanitarian response such as the KRCS, UN agencies and NGOs (UN-OCHA, 2006).

The government of Kenya initiated a rehabilitation programme estimated at Ksh 8.7 billion or US$108 million following the El Niño flood event of 1997/98 (Mogaka et al;

2006). Contributions came from the Kenyan Government, the World Bank, the African Development Bank (ADB), and Agence Francaise de Development (AFD). Table 5 indicates some of the costs of rehabilitation projects in various sectors.

Table 5: Costs of Major Rehabilitation Projects in Response to the 1997/98 El Niño floods in Kenya

	No. of projects					Contract prices (millions of Kshs.)				
	Rural		Urban			Rural		Urban		
Province	**Water**	**Roads**	**Roads**	**Health**	**Total**	**Water**	**Roads**	**Roads**	**Health**	**Total**
Nyanza	6	6		5	**17**	132	241		29	**402**
Rift Valley	4	6		6	**16**	201	417		33	**651**
North	6	3		8	**17**	79	112		3	**194**
Eastern	10	5		8	**23**	144	443		42	**629**
Coast	7	7		16	**30**	116	257		66	**439**
Western	5	7		2	**14**	181	192		9	**382**
Nairobi/Nyanza			8		**7**			2108		**2108**
Coast										**0**
All Districts	4				**4**	45				**45**
Total	**42**	**34**	**8**	**45**	**128**	**898**	**1662**	**2108**	**182**	**4850**

Adapted from Climate Variability and Water Resources Degradation in Kenya: Improving Water Resource Development and Management (World Bank, 2006)

The cost of annual relief and rehabilitation measures in Kano Plains is estimated at US$ 600,000 (Eitel and Ochola, 2006). Table 6 indicates the amount spent on damages and relief provision in Kano Plains and Budalang'i as a result of perennial flooding on Rivers Nyando and Nzoia respectively annually. Emergency relief operations cost the government an estimated Ksh 100 million annually.

Table 6: Annual Government Spending on Flood Relief and Rehabilitation in Nyando and Nzoia

Catchments	**Affected**		**Costs in Millions (Ksh)**	
	Floodplains	Victims	Damages	Relief & Rehabilitation
Nzoia	Budalang'i	12,000	46	63
Nyando	Kano Plains	5,000	49	37
Total		**17,000**	**95**	**100**

Table showing the annual cost of relief and rehabilitation and number of people affected in Nzoia and Nyando sub-catchments annually- Adapted from: WMO and GoK (2004)

The cost of rehabilitation includes the cost of dyke reconstruction amounting to Ksh. 37 million annually. It is further estimated that about 1 million US$ is spent on relief and rehabilitation of about 12,000 people displaced due to flooding on the banks of River Nzoia annually. (WMO and GoK, 2004)

The Kenya Red Cross Society (KRCS) engages in resource mobilization to facilitate emergency relief operations through making flood appeals. Following the October-November 2006 flood disaster, a flood appeal for over half a billion Kenya Shillings was made to assist 300,000 flood victims over a period of three months.

KRCS through its Western Region Office played a crucial role in the coordination and logistical support to the government and other humanitarian relief workers. This included transportation and distribution of relied items (food and water and non food items such as medical supplies, clothing and mosquito nets) donated by the government, donor agencies, private sector organizations and well wishers. Table 5 summarises the number of relief beneficiaries in Budalang'i and Nyando districts following the 2006 flooding.

Table 7: Relief Beneficiaries in Nzoia and Nyando sub-basins during the 2006 Flood

Catchments	Affected			Relief Beneficiaries	
	Districts	Population Affected	Displaced	Persons	Households
Nzoia	Budalang'i	15,888	2,648	13,560	2,260
Nyando	Nyando	6,720	1,120	3,360	560
Total		**22,608**	**3,768**	**16,920**	**2,820**

Table showing the number of people affected at district and household level during the recent flooding of 2006

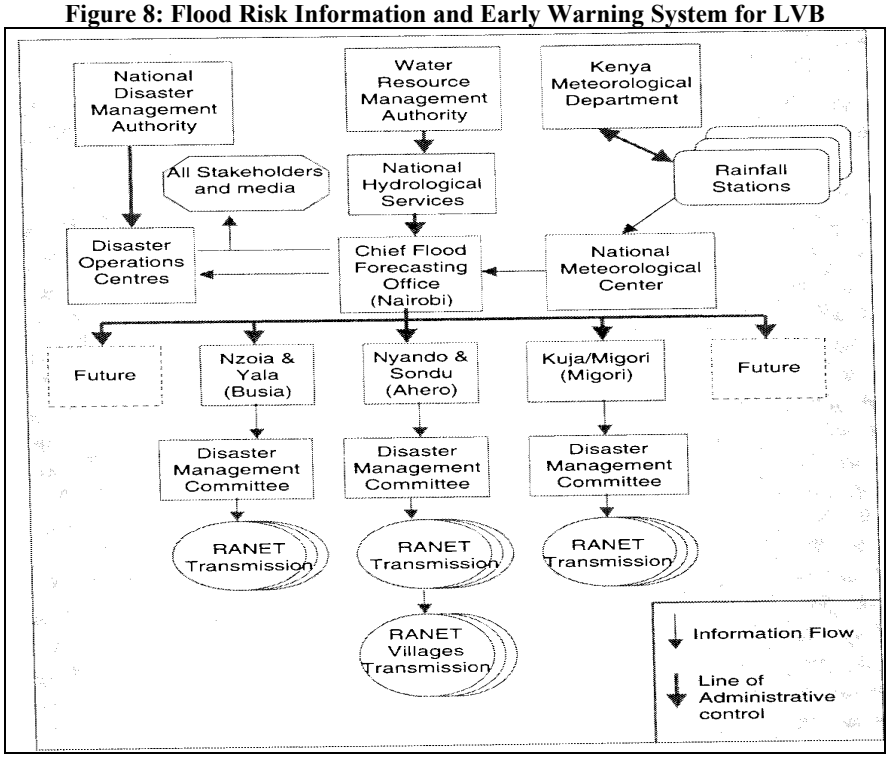
Source of data: Kenya Red Cross Society (2007)

During the 1997/98 El Niño flood, it is estimated that operational costs to the World Food Programme is distributing relief food was US$1,100 per ton for each air drop. A total of 7,414.23 MT was distributed at a cost of US$4,117,734 to 641,451 beneficiaries in seven districts including Garissa and Tana River (Gadain et al; 2006)

Flood Early Warning Systems (FEWS)

Flood early warning system is one of the is one of the most effective methods of reducing risk to life and property amongst non-structural flood management strategies. A Flood Risk Information and Early Warning Systems (FRIEWS) for Lake Victoria Basin has been proposed. The necessary measures for its implementation have been put in place. The system's implementation structure is summarised in (Figure 8).

Figure 8: Flood Risk Information and Early Warning System for LVB



Schematic representation of the Proposed Flood Forecasting and Dissemination Mechanism for Flood Early Warning in Lake Victoria- Source: WMO and GoK (2004)

The early warning system requires highly specialised technical and institutional capacities with a high cost implication for its effective implementation. The costs are relatively lower as compared to other structural measures. With regards to technical needs, flood forecasting and river gauging stations have been established in all the five sub-catchments in Lake Victoria Basin (Table 8). Flood forecasting stations are located upstream of the rivers while the river gauging stations are located downstream-as close to the foothill as possible.

Table 8: Technical Capacity Needs for Flood Early Warning in Lake Victoria Basin

River	Station Numbers/Name		Type of Modelling	
	Base	Flood Forecasting	Rainfall-Runoff	Channel Routing
Nzoia	1DA02	1EF01	✓	✓
Yala	1FE02	1FG02	✓	✓
Kuja	Gogo Dam	1KB05	✓	✓
Nyando	None	1GD03	✓	
Sondu	None	1JG01	✓	

Table showing the type of stations and forecasting models available in LVB-
Source of data: WMO and GoK, 2004

The Ministry of Water and Irrigation has a number of flood forecasting hydrological models necessary to implement the early warning system. These include the simple statistical rainfall-runoff and more sophisticated deterministic models such as the Galway Flood Forecasting System Model (GFFS) and Geo Spatial Flood Forecasting Model (Geo SFM). The implementation of the flood early warning system will involve the following government agencies; the Kenya Meteorological Department (KMD) will play a crucial role in handling rainfall and flood data collection and processing and forecasting. KMD's other role will be to transmit data every three hours to the National Meteorological Centre through the Meteorological Station in the lakeside town of Kisumu. This information will then be relayed to the National Disaster Operation Centre (NDOC). NDOC will be responsible of mobilizing provincial and district level units for rescue and relief operations discussed earlier. NDOC will work closely with Disaster Management Committees at the community level.

Disaster Management and Institutional Responses

The National Disaster Operations Centre (NDOC) is responsible for management of all disasters in the country including floods through the Disaster Management Committees (DMC) at the provincial and district levels, under the chairmanship of the Provincial Commissioner. NDOC coordinates post flood disaster related activities of various Ministries at the district level. NDOC receives weather forecasts and early flood warnings from KMD and makes an assessment of the magnitude of the impending floods and its disaster potential. The information is then conveyed to the Provincial District Management Committees. The Committees are responsible for rescue and relief operations through multidisciplinary teams at the district and community level.

2.2 Policy and Legislative Framework

At the moment, Kenya still lacks a comprehensive flood risk management policy and relies of the existing flood risk reduction measures and strategies proposed in the draft National Disaster Management Policy of 2007[12] and the Strategy for Flood Management in Lake Victoria Basin of 2004. However, there are a number of sector specific pieces of legislation that attempt to provide policy direction on flood management in Kenya. These include; the Water Act, the Environmental Management and Coordination Act (EMCA), the Kenya Red Cross Act, Forest Act, Agriculture Act, Land Act, Kenya Police Act the Chief's Act among others (RoK, 2004; RoK, 2007; WMO and GoK, 2004). Under the Chief's Act (Cap.128), power is vested in the Minister to call upon local chiefs to enlist the services of any able-bodied adult to respond to an emergency such as floods.

The Water Act 2002 (Cap 372) provides for a catchment management strategy for the protection and control of water resources, including preventing and reducing intensity of water-related hazards such as floods. It also addresses existing weakness in flood data collection and monitoring and provides for acquisition of land for state owned schemes in line with the Forest and Land Use Acts

[12] The draft National Disaster Management Policy of 2007 revised in 2009 proposes a continuum of measures such as preparedness and prevention with specific strategies such as flood risk vulnerability assessment and mapping and Integrated Flood Management (IFM) Projects.

The National Environmental Management Authority (NEMA) created by the Environmental Management and Coordination Act No 8 of 1999 is charged with the responsibility of preventing environmental hazards such as floods and reverse environmental degradation. The Act also provides for protection and conservation of the environment with specific reference to rivers, lakes and wetlands.

The Kenya Red Cross Society Act (Cap. 256) established the Kenya Red Cross Society (KRCS) with expertise in research, relief, rescue and emergency planning. The National Society work on responding to humanitarian crises such as floods and assists government operations logistically during flood emergency relief provision. It works closely with other stakeholders such as UN agencies. The Act recognizes KRCS as a voluntary emergency agency with expertise disaster risk reduction programmes.

The Local Authority Act Cap. 265 provides for the establishment of a disaster management office in every Local Authority to liaise with central government and its agencies and other organizations dealing with disasters such as floods. It also identifies special powers on resource mobilization that may be used in the event of a local disaster have been established within the Act.

3.0 Scaling Feasibility and Costs of Adaptation Interventions

The cost of adaptation interventions for flood risk in Kenya is yet to be clearly established due to the existing challenges in undertaking comprehensive flood risk assessment studies. More feasibility studies applying appropriate methodologies of flood risk losses must be undertaken across the country to ascertain the real costs of adapting to flood risk in the country in preparation of future risks.

4.0 Potential Benefits of Adaptation Interventions to Livelihoods

Physical Safety

Safety of humans and livestock can be achieved through flood risk mitigation and adaptation options, mainly structural measures that provide physical protection to life and property. Living conditions of thousands of displaced persons can be improved if not saved from death with well-coordinated evacuation efforts. For instance during the exceptional floods of October- November 2006 in Kano Plains, Yala Swamp and other low-lying parts of the LVB, the Kenyan military comprising of Kenya Navy, the Army and the Air Force provided assistance on a massive scale to the civil authorities in flood and famine relief. As a result of these operations, loss of human lives was reduced.

Financial Savings and Income Generation

In general, flood risk management projects have the potential of reducing flood losses thus allowing for financial savings to be realised by vulnerable communities and the government. The government spends huge sums of money on flood emergency and relief programmes and redirects millions of shillings towards responding to humanitarian emergencies such as flood in the country. Flood risk management projects with key community driven development components have the potential of generating additional income at household level, reducing poverty levels at household level and funding long-term development projects in the country.

Community Empowerment

Capacity building of stakeholders such as community based and local non-governmental organisations and individuals to implement community based flood risk management projects increases community ownership of the projects like in the case of flood protection in Nyando that were constructed by the local community. This is beneficial in maintaining flood risk reduction structures. This minimises high financial costs incurred to rehabilitate the structures after they are breached by heavy floods due to destruction by community members who lack knowledge on the importance of maintaining the structures.

Gender and Education Issues

The most vulnerable groups in any community are the women. Participation of women and other groups in the community in decision-making processes including flood risk reduction measures is therefore a critical part of ensuring the effectiveness of the strategies. Public education and awareness creation efforts should therefore target women as key stakeholders in flood risk reduction measures. Community education programmes to increase awareness and instil behavioural change have the potential of reducing human vulnerability to floods through understanding the nature of flood risk and how to minimise individual and household risks.

5.0 Environmental Benefits

In flood-prone areas, preventive measures should be taken to reduce possible adverse effects of floods on the environment such as aquatic and terrestrial ecosystems, including water and soil pollution and conservation. For instance, flood management measures can minimise diffuse pollution arising from surface water run-off, minimise the amount of surface water runoff and infiltration entering foul and surface water sewerage systems, and maintaining recharge to groundwater subject to minimising the risk of pollution to groundwater.

6.0 Barriers and Constraints to Existing and Future Adaptation Interventions

Policy and Institutional

The lack of a flood management policy in Kenya is a major challenge to adapting to the adverse impacts of floods. Karanja et al., (2001) and Gadain et al., (2006) alludes to the policy gap with regard to flood management and the lack of overall disaster management legislation in Kenya. The country also lacks coordinated institutional structures and arrangements to mitigate the negative impacts of floods. Lack of advance flood warning takes the public unaware, leaving no lead time to take preventative measures. In the absence of such a policy and legislation to act as a management tool and ensure effective response to disasters including flood, flood risk management in Kenya has remained largely inconsistent, uncoordinated and reactive as opposed to taking a more proactive approach (RoK, 2007, Karanja et al., 2001). This was evident during the El Niño floods of 1997/98 that was rather slow and uncoordinated despite the warnings that were issued prior to the event.

Financial, Human and Technical Resources

Financial, human and technical resources for sustainable flood management measures have always been scarce in developing countries like Kenya. Such resources are a very important part of institutional arrangements. Lack of these resources limits the country's responsiveness to flood disasters. Many institutions charged with the responsibility of handling flood disasters in the country are faced with inadequate budgetary allocations and depend on unconditional donor support. Lack of skilled human resources such as flood risk managers and modern gauging stations to monitor flood levels also hampers the process of flood risk management in the country.

Community Participation and Sensitization

The Kenyan community has not been sufficiently sensitised on flood risk management in the country's flood-prone regions. Lack of flood risk information at the community level especially, in preparedness and coping mechanisms is a major set back to long-term flood risk reduction strategies. For instance, riverine communities are not informed on the importance of maintaining dykes in dry seasons to avoid flooding during wet seasons. The communities are also left with no options of where to evacuate to in the event of a flood. This is further aggravated by high population that forces people to invade river banks due to pressure on scarce land.

Infrastructural

There are significant institutional weaknesses that pose major infrastructural challenges. For instance, there a limited hydrological observation stations to monitor flood levels and weak database management and analysis methods. Over the years there has been a deterioration in the condition of the river gauging stations due to lack of regular repairs and preventative maintenance after major flood events such the 1998/98 El Niño flood. Automatic data sensors lack frequent recalibration.

Inadequate information and data

Inadequacy of flood monitoring stations to generate data and information, leads to poor flood risk management planning. Flood damage assessments carried out by the Department of Resource Survey and Remote Sensing (DRSRS), local development authorities is only done occasionally and is mainly qualitative. In addition, there are no set procedures for assessment of monetary value of damages. Another challenge is that there is normally a lag time between the occurrence of damaging floods and the assessment studies/compilation damage data.

Data from staff gauges and automatic water level recorders cannot be used in flood forecasting based on channel routing models since they have not been connected to a common reference datum.

7.0 Conclusions

Flood risk management has the potential of reducing flood damages and losses resulting to huge economic savings. The government in particular stands to spend less on responding to emergency flood disasters and can invest this in other long-term national development projects.

Flood risk management projects with deliberate community involvement efforts have the potential of generating additional income at household level and reducing poverty levels.

The1997/98 El Niño floods had widespread impacts in key sectors of the economy across the country.

A post El Niño rehabilitation programme was initiated by the government of Kenya at cost of approximately Ksh 8.7 billion or US$108 million. A majority of the projects focused on rehabilitating roads and water infrastructure and provision of health services at a cost of Ksh 4.85 billion in 22 districts of the country.

The government spends approximately Ksh 37 million is spent annually for dyke rehabilitation in the western Kenya floodplains. During the short rain season of 2009, a total of Ksh 40 million has been earmarked for the rehabilitation of dykes in Budalang'i in anticipation of the short rains that might be accompanied with El Niño .

The World Bank funded, Western Kenya Community Driven and Flood Mitigation Project has been designed to address catchment management, multi-purpose flood management structures, floodplain management and structural flood mitigation structures in Nzoia and Yala basins at total cost of US$73.2 million. The projet is being implemented by the GoK through the Ministry of State for Special Programmes.

The government initiated the construction of River Nzoia dykes in 1977 at a cost of Ksh 17 million. The project was completed in 1984 and the dykes measure 36.4 km in length with 16.2 km in the northern and 18.4 km on the southern banks of the River and offer protection to residents in Busia and Budalang'i districts in western Kenya.

The local community with assistance from local administrative units initiated dyke construction on River Nyando that measure only 1 metre high.

The Seven Forks Dam project consists of a series of multipurpose reservoirs in the upper catchment of Tana River. In addition to serving as flood control measures, the dams were developed as part of the hydropower scheme and for irrigation use. The first dam, Kindaruma was completed in 1968 followed by Kamburu (1975), Gitaru (1978) and Masinga (1981) and Kiambere in 1981.

There are 15 RANET information stations established in the country three of which are located in Kisumu, Kakamega and Eldoret towns of western Kenya. A fourth station is currently being established in Budalang' i.

The cost of annual relief and rehabilitation measures in Kano Plains alone is estimated at US$ 600,000. A further US$ 1 million is spent to assist 12,000 persons that are displaced annually due to flooding on the banks of River Nzoia. In general emergency relief operations cost the government an estimated Ksh 100 million annually.

The Kenya Red Cross made a flood appeal for over half a billion Kenya shillings to assist 300,000 flood victims for 3 months following the October-November 2006 flood that affected over 723,000 persons across the country

Flood forecasting and early warning system requires highly specialised technical and institutional capacities with a high cost implication for its effective implementation. The cost is believed to be relatively lower as compared to other structural measures.

Major challenges to flood risk management in the country include the lack of a comprehensive policy and lack of financial, human, and technical resources required for effectively implementing an early warning system similar to the one proposed for Lake Victoria basin. Lack of data and low community involvement are also key challenges.

References

'Best Practices on Flood Prevention, Protection and Mitigation,' Available at www.actif-ec.net/library/EUBestPracticeFinalversion.pdf

Eitel, B., and Ochola, S.O. (2006), 'River Nyando Basin Project' (Institute of Geography, University of Heidelberg). Available at http://www.geog.uni-heidelberg.de/physio/forschung/nyandobasin.htm

Gadain, H., M., Bidault, N., Stephen, L., Watkins, B., Dilley, M., and Mutunga, N. (2006), in 'Natural Disaster Hotspots: Case Studies, Reducing the Impacts of Floods through Early Warning and Preparedness: A Pilot Study for Kenya', Disaster Risk Management Series No. 6, (Washington DC: World Bank).

Government of Kenya (2007), 'Mission Report to Access the Impacts of Floods in Budalang'i and Rachuonyo Districts in Western Kenya', (Nairobi: Ministry of State for Special Programmes).

ICPAC, (2007), 'Climate Change and Human Development in Africa: Assessing the Risks and Vulnerability of Climate Change in Kenya, Malawi and Ethiopia', (Nairobi: UNDP).

Karanja, F., Ogallo, L.J., Mutua, F. M., Oludhe, C., Kisia S. (2002), 'Kenya Country Case Study: Impacts and Response to the 1997-98 El Niño Event', Available at http://www.ccb.ucar.edu/un/kenya.html

Kenya Red Cross Society (2007), 'Operations Update,' Kenya: Floods Update No. 14

Kenya Red Cross Society (2006), 'Preliminary Appeal,' Kenya: Floods Preliminary Appeal No. 1/2006

Osbahr, H., Viner, D. (2006), 'Linking Climate Change Adaptation and Disaster Risk Management for Sustainable Poverty Reduction: Kenya Country Study'.

Republic of Kenya (2007), 'National Policy on Disaster Management,' (Nairobi: Ministry of Special Programmes).

United Nations Office for the Coordination of Humanitarian Affairs (2006), 'Kenya Floods: OCHA Situation Report No. 2'. Ref: OCHA/GVA 2006/0243 Available at http://www.reliefweb.int accessed on 27 March 2008

United Nations Office for the Coordination of Humanitarian Affairs (2006), 'Kenya Floods: OCHA Situation Report No. 3'. Ref: OCHA/GVA 2006/0234 Available at http://www.reliefweb.int accessed on 27 March 2008.

Smith, K., and Ward, R.C. (1998), 'Floods: Physical Processes and Human Impacts', (Chichester: Wiley).

World Resources Institute; Department of Resource Surveys and Remote Sensing, Ministry of Environment and Natural Resources, Kenya; Central Bureau of Statistics, Ministry of Planning and National Development, Kenya; and International Livestock Research Institute, (2007), 'Nature's Benefits in Kenya, An Atlas of Ecosystems and Human Well-Being', (Washington, DC and Nairobi: World Resources Institute). Available at http:// www.wri.org/

World Meteorological Organisation, Ministry of Water Resources Management and Development, Kenya and Associated Programme on Flood Management, (2004), 'Strategy for Flood Management for Lake Victoria Basin, Kenya', Available at http://www.apfm.info/pdf/strategy_kenya_e.pdf

Dartmouth Flood Observatory http://www.dartmouth.edu/~floods/Archives/MasterSpreadsheet.htm
Emergency Data: http://www.emdat.be/

Ministry of Water: http://www.water.go.ke/docs/WaterAct2002.pdf
National Environmental Management Authority: http://www.nema.go.ke/about.html
Mogaka H, Gichere, S., Davis R., and Hirji, R. (2006), Climate variability and water resources degradation in Kenya: improving water resources development and management, World Bank

United Nations Environment Programme (UNEP), Government of Kenya (GoK), Regional Centre for Mapping of Resources for Development (RCMRD) and United States Geological Survey (USGS), (2009), Kenya Atlas of Our Chnaging Environment

Otiende B., (2008), Risk Assessment for Extreme Riverine Floods in Kenya: A Tool for Flood Risk Management