CHAPTER TWO

VULNERABILITY AND ADAPTATION TO CLIMATE VARIABILIY AND EXTREME (FLOOD)

2.0 Introduction

The study of vulnerability of human and natural systems to climate variability and their ability to adapt to variability in climate hazards is a relatively new field of research. The recognition of climate variability as a global environmental threat has resulted in many assessments of the vulnerability, adaptation, and the potential effects of climate variability in different part of the world (Schiller *et al.*, 2001). The focus of this chapter is to review the growing body of literature on vulnerability and adaptation to climate variability and extremes. The literatures are presented in themes for better understanding, for example, flood and climate variability, determinant of vulnerability and adaptation, climate variability and human health, wildlife and eco-tourism, etc. This chapter also present a conceptual framework that is applied consistently to studies of vulnerability and adaptation by researchers with different background.

2.1 Flood and climate variability

Water-related disasters, i.e. floods and droughts, are known to cause devastating livelihood impacts, suffering and economic damages. Due to these implications, the topic of extreme hydrological events has drawn increasing attention in the climate variability literature. In hydrology, two hydrological extreme events are recognized: flood and drought. While the former represents abundance, the latter depicts scarcity. Scientific studies and human experiences have shown that both extremes have their impacts on water resource availability (Iyanda, 2003). Flood, which is the main concern in this study, is described as a natural hydrological extreme event affecting the flow regime of all rivers particularly during the rainy season. Flood is defined as the temporary over-flow of a river onto adjacent lands not normally covered by water (Middleton, 2003). It is

particularly interesting to note that studies on flood have gained scientific recognition and an extensive body of scientific literature exists on the subject.

All rivers are subject to flooding in the hydrological sense of inundation of riparian areas by stream flow that exceeds bank-full capacity (Iyanda, 2003). The point at which a stream channel discharges an over bank surplus is the flood stage. Field studies have also shown that some rivers are at the flood stage once in a hydrological year, while others carry floodwater twice (NEDECO and Balfour, 1961; Sule, 1984). Most rivers exhibit a single flood regime, for example, rivers Benue and Kaduna that are both tributaries of the River Niger in Nigeria. Some rivers, however, have double flood regimes, such as the River Niger in Nigeria and River Nile in Egypt (Iyanda, 2003).

On flood frequency, Deyer (1988) states that flood flows can occur on the average as often as once every year or two years in the wet tropical and temperate climates and as infrequently as once in 1000 years. Both river-channel and urban floods are recognized as the most universally experienced and serious environmental problems of contemporary socio-economic importance that affect people, their environment and their activities on a global scale in many countries of the world. People have been living with flood since the dawn of civilization.

More recently, the number of flood events that have been documented appears to be on the increase. A global increase of large flood frequency between 1985 and 2003 seems to be evident (Fig. 2.1). Interestingly enough, figure 2.1 indicates a high frequency of floods in 1997 and 1998, as well as the increase of flood numbers during the last 4 years. This point will be re-examined in subsequent chapters.

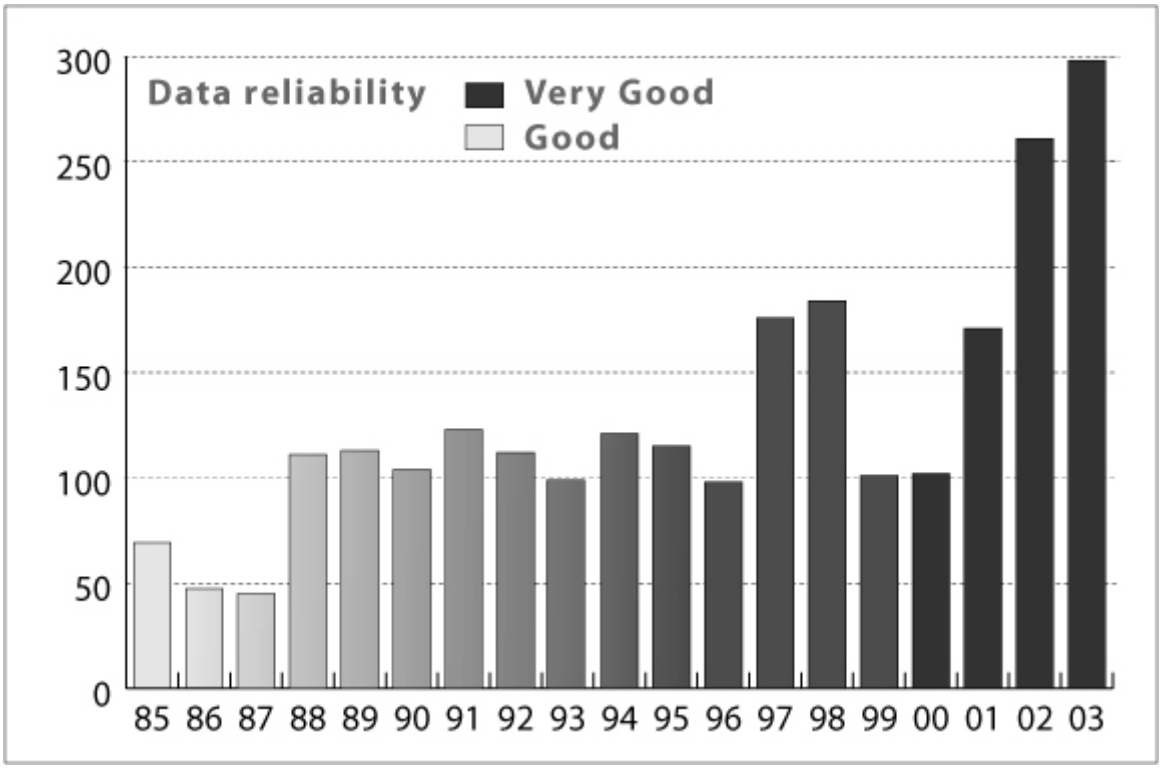

Figure 2.1: Global flood frequency between 1985-2003: (Source Dartmouth flood observatory. **http://www.dartmouth.edu/%7Efloods/archiveatlas/** May 11, 2005).

In Nigeria, several river floods have occurred such as the Cross River Basin flood of 1970, the Lower Ogun River Basin annual flood and the River Ogunpa flood in Oyo State (Anon, 1990). Iyanda, (2003) documented flood occurrences along the River Niger, in 1964, 1988, 1994, 1998 and 1999 that were all devastating. In East Africa, the flood of 1998, for example, impacted on agriculture and livelihoods. Also the flood from tropical cyclones in Mozambique that occurred in 2000 caused considerable damage to property and infrastructure (Washington *et al.*, 2004, cited in Vogel, 2005). The Mozambique flood reduced the annual growth rate from 8 to 2 percent (Washington *et al.*, 2004, cited in Vogel 2005) and displaced 2 million people (IPCC, 2001).

2.2 Determinants of vulnerability and adaptation

All hazards, such as floods and droughts, occur within a specific socio-economic and/or biophysical context. There are two sets of hazards that lead to vulnerability, that include, traditional and modern hazards (Eyles and Sharma, 2001). Traditional hazards are

associated with a lack of development - they are usually related to poverty; lack of access to safe drinking water; inadequate basic sanitation in the household and community; indoor air pollution from cooking and using biomass fuel; and inadequate solid waste disposal (WHO, 1990; Eyles and Sharma, 2001). Modern hazards are usually associated with unsustainable development practices and include water pollution from populated areas, industry, and intensive agriculture; urban air pollution from vehicular traffic, coal power stations, and industry; climate variability; stratospheric ozone pollution (depletion); and trans-boundary pollution (WHO, 1990; Eyles and Sharma, 2001). Traditional and modern hazards can combine enhancing impacts, for example, diffusion of infectious diseases, especially in the developing world (Eyles and Sharma, 2001), hence increasing vulnerability and also often reducing coping capacity.

The impact of hazards can be heightened by the degree of resilience or vulnerability a society, group or ecosystem exhibits. Vulnerability depends critically on the local context in which vulnerability occur. Smit *et al* (2001) in the IPCC TAR, citing Smit *et al*. (1999), describe vulnerability as the degree to which a system is susceptible to injury, damage or harm (one part- problematic or detrimental part- of sensitivity). Here, the definition of vulnerability is essentially seen as a state variable, determined by the internal properties of a system. For social systems it could be referred to as social vulnerability (Brooks, 2003; Adger, 1999; Adger and Kelly, 1999; Kelly and Adger, 2000). Certain factors will make a system particularly vulnerable to specific types of hazard. Other factors, however, might mean that a system has a high capacity to adapt to some hazards but not others (Adger *et al.*, 2004). Therefore, the factors that make a system vulnerable to hazard will depend on the nature of the system and the type of hazard in question (Brooks *et al.*, 2004). For instance, abundant groundwater resources will enable a country to adapt to an increased frequency of drought by expanding irrigation (Adger *et al*., 2004). Also, a weak regulatory environment and the existence of informal markets might enable people to adapt to drought through crop and income diversification. None of these factors, however, will directly reduce people's vulnerability to, or help them to adapt to floods or windstorms (Adger *et al.*, 2004).

Therefore, other factors will act to influence vulnerability and the capacity of people to adapt to a range of hazards. Poverty, for example, might prevent people from investing in the farm inputs necessary for diversification and the means to transport their produce to market (Adger *et al.*, 2004). It is also likely to be associated with poor quality housing that is easily damaged by flood or storms, as in the case of Shiroro communities in Niger State. High levels of inequality are likely to result in the formation of highly vulnerable groups that are financially and socially marginalized (Adger *et al*., 2004; Brooks *et al.*, 2004). These groups lack the financial resources for adaptation and may be forced to settle in exposed areas such as floodplains, unstable hill slopes or regions of marginal rainfall. These are factors that determine vulnerability and capacity to adapt to a wide range of hazards (Adger *et al*., 2004; Brooks *et al*., 2004). Crawford (1980) as sited in Watts (1983), analysed the impact of stochastic variability, such as weather, on household resiliency in Kano, Nigeria and determined that the poor take a longer time to recover from impact of weather than their wealthier counterparts. The poor, as cited in the TAR are the most vulnerable and are likely to be affected most by climate variability. Vulnerability to climate variability is closely related to poverty. The poor, therefore, are amongst those least able to effectively respond to climatic variability particularly extreme events (Kates, 2000).

Furthermore, certain regions of the world are more severely affected by climate variability, than others (Kates, 2000), for instance, factors that make a rural community in semi-arid Africa vulnerable to drought will not be identical to those that make areas of wealthy industrialized nation such as United States of America vulnerable to flooding, wind storms and other extreme weather events (Brooks et al., 2004; Adger *et al.*, 2004). Several studies such as Mbithi and Wister, (1973); Kamau *et al*., (1989); Reardon and Matlon (1989); Cutter (1996); FIVIMS (2000); FEWSNET (2000) have identified the poor as the population groups most likely to experience the adverse effects of drought and other natural hazards or stresses induced by conflict or other social, economic or political forces. Developmental factors including poverty, health, status, economic inequality and elements of governance etc, are most likely to influence vulnerability to a wide variety of hazards in different geographical and socio-political contexts (Brooks *et*

al., 2004). The vulnerability of a region depends to a great extent on its wealth, and that poverty severely limits adaptive capacities (Watson *et al.*, 1998). Vulnerability to climate risk and enhanced adaptive capacity depends on the level of economic development and institutions (IPCC, 2001). Moreover, socio-economic systems 'typically are more vulnerable in developing countries where economic and institutional circumstances are less favourable' (Watson *et al.,* 1996). For instance, income diversification might be important determinants of vulnerability to drought for rural communities in Africa (Brooks *et al*., 2004). While in Niger State of Nigeria, one of the determinants of vulnerability to flood is the poor quality of physical infrastructure.

Other relevant factors influencing vulnerability to climate extremes in flood-risk areas such as that profiled here, to some extent includes the price of a particular food crop, the number of storm shelters available for the use of coastal or riverside communities or the existence of regulations concerning the robustness of buildings (Brooks *et al.,* 2004). Although the relative importance of these different factors will exhibit some variation, such factors may be viewed as the foundation on which specific measures for reducing vulnerability and facilitating adaptation are built (Brooks *et al.,* 2004). A rural community, for example, is more likely to be serviced by transport infrastructure if it is effectively represented at the political level. Building codes are more likely to be enforced if corruption in the building industry and regulatory agencies is minimised (Brooks *et al*., 2004).

In addition, physical factors including temperature and precipitation in the tropics may also influence vulnerability. In areas, for example, where some crops are near their maximum temperature tolerance and where dry land, non- irrigated agriculture dominates, yields are likely to decrease for even small changes in climate (IPCC, 2000a). Africa and Latin America, for example, show a projected decrease in overall agricultural productivity of up to 30% during the next century (IPCC, 2000a). Therefore, there may be increased risk of hunger in some locations in the tropics and subtropics where many of the world's poorest live (IPCC, 2000a). Climate variability mainly through increased extremes (flood and drought) and temporal/spatial shifts will worsen food security in

Africa (IPCC, 2001). A common theme is the fact that changes in temperature and precipitation occur unevenly and that climate variability impacts are unevenly distributed around the globe. This is mainly coupled with the fact that resources and wealth are distributed unevenly. Though vulnerability differs substantially across regions, it is also recognized that "even within regions, impacts, adaptive capacity and vulnerability will vary" (IPCC, 2001: 15).

Having briefly described vulnerability, adaptation and ways of enhancing resilience in the face of risks are now addressed. Adaptation to climate is the process through which people reduce the adverse effect of climate on their health and well being and take advantage of the opportunities that their climatic and wider environment provides e.g. social capital, institutional assets etc (Burton, 1992, as cited in Smit *et al*., 2000). Handmer *et al.,* (1999), posits that many regions and countries will, however, be capable of adapting to climate variability, but that poorer countries and regions will have difficulty responding to climate variability. Kelly and Adger (2000) argue that vulnerability is contingent on estimates of the potential climate variability and adaptive responses. In other words, 'the level of vulnerability is determined by the adverse consequences that remain after the process of adaptation has taken place' (Kelly and Adger 2000: 327). Such vulnerability, 'outcome' vulnerability is one arena receiving attention. Of interest, however, is also determining 'inherent' vulnerability, which is a function of various dimensions (e.g. social, physical and other dimensions). An example of social dimension includes, poverty and inequality, marginalization, food entitlements, access to insurance, and housing quality.

Most efforts to address climate variability to date have focused on mitigation, or preventive action to limit green-house gases, rather than on adaptation (Kates, 2000). Authors such as Lorenzoni *et al.,* (2000) and Sharma and Kumar (1998), for example, argue that disproportionately greater attention has been paid to climate variability mitigation than to adaptation measures. Different groups and places within countries differ in their ability to adapt. Divisions, moreover, between rich and poor translate into differentials in people's ability to adjust and in access to adjustments (Kates, 2000).

Successful adaptations therefore, it is suggested, depend upon technological advances, institutional arrangements, availability of financing, and information exchange (Watson *et al.,* 1996). The ability of affected communities to adapt to risks to health also depends on social, political, and economic circumstances (Watson *et al.,* 1996). There is, therefore a basic and general need for public health infrastructure (programs, services, surveillance systems) to be strengthened and maintained to enhance adaptation.

2. 3 Climate variability and Human Health

Having briefly examined some of the previous literatures on vulnerability and adaptation to climate change, attention is now on the climate impacts on human health, wildlife and Eco-tourism, fisheries, water resources, human security, and social resilience. For each anticipated adverse health impact, there is a range of social, institutional, technological and behavioural adaptation options that could lessen that impact (Watson *et al.,* 1996). Every change in the physical and social environment (climate variability) has an effect on health and on the capacity of individuals and societies to cope with health problems (Bloom, 2004). The reports of WHO (2003) and IPCC TAR (2001) on the impacts of climate variability on health stress difficulties of precise and localised projections but conclude that climate variability will present major and largely unfamiliar challenges to human health. For instance, the distribution of organisms and animal vectors may change due to climate variability, resulting in the spread of malaria and other infectious diseases (Bloom, 2004). Therefore, human health may be affected by changes in nutrition (Bloom, 2004; Devereux and Edward, 2004) and access to clean water (Burton and May, 2004; Denton, 2004; Bloom, 2004) resulting from climate variability and extremes. In some African countries, vulnerability assessment has been conducted on the impacts of climate variability on human health. The researches show that human health is sensitive to climate and synoptic weather patterns. This is because many maladies are related to temperature and precipitation regimes (Robert *et al.,* 2003). The key factor affecting the vulnerability of human health is the strength of the public health system, while countries with weak public health systems may be at greater risk because they would be less able to prevent or contain outbreaks of diseases or other health problems associated with global climate variability (Watson *et al.,* 1996).

2. 4 Wildlife and Eco-tourism

The impacts of global climate variability also impacts negatively on wildlife and eco-tourism. The impacts of climate variability on African wildlife have not been intensively studied relative to anthropogenic impacts (Markham, 1996). Wildlife is likely to be affected by ambient precipitation and temperature changes, as well as by geographic shift in ecosystem (Robert *et al.,* 2003). This is because animals dependent on intermittent streams or lakes may be at a particular risk (Robert *et al.,* 2003). The population of wildlife in Africa is at risk from drought (Watson *et al.*, 1998), as a result of climate variability, which increases aridity. Vulnerability studies carried out in Malawi by Mkanda (1999), for example, shows potential declines in Nyala (Tragelaphus) and Zebra (Aquiferus), in Lengwe and Nyala national parks. It was concluded that Nyala is vulnerable to climate induced habitat changes.

2.5 Fisheries and Climate variability

Global climate variability is projected to alter freshwater temperatures, water chemistry (e.g. oxygen levels) and circulation (Robert *et al.,* 2003). Vulnerability assessments on fisheries were conducted using quantitative analysis in five African countries, which includes, Botswana, the Gambia, Kenya, Mauritius and South Africa (Robert *et al.*, 2003). The result suggests that fish in small rivers and lakes or where temperature or precipitation changes are greatest are most at risk. Temperature increase and change in thermal niches will alter species distribution and productivity of marine and estuarine fisheries (Robert, *et al.,* 2003). Loss of coral reefs due to bleaching and other factors will adversely affect habitat and fish populations (Watson *et al.*, 1996). About 950 million people worldwide depend on fish as their primary source of protein (Watson, *et al.*, 1996). Therefore, since significant portions of the world population depend on fish for protein, especially in African countries, fishery farming (aquaculture) and transplanting are two practical adaptation options in some regions of Africa (Hlowhowskyj *et al.*, 1996).

2.6 Climate variability and water resources

Among the 19 countries around the world currently classified as water stressed, more occur in Africa than any other continent (Watson *et al.,* 1997). Most of the vulnerability analysis of water resources focused on the portion of precipitation on land that ultimately reaches river or lakes. Other assessments on vulnerability and water resources, however, considered factors such as water supply and demand, flooding and drought, river salinity, water quality, irrigation and hydroelectric generation (Muta, 1996; Strzepek *et al.,* 1996 as cited in Robert *et al* (2003: 105). Reduction in precipitation projected by some GCMs, for the Sahelian and Southern African countries, if accompanied by higher inter-annual variability, could be highly detrimental to the hydrological balance of the continent and water dependent activities (Robert *et al.,* 2003). Reduction in water level in reservoirs and rivers could adversely affect the quantity of water by concentrating sewage and industrial effluents, thereby exacerbating water borne diseases and reducing the quality and quantity of fresh water available for domestic use (Strezepek and Kaczmarck, 1996). Developing adaptation strategies for fresh water resource affected by global climate variability is complicated by the fact that water supplies could either increase or decrease based on inter-annual precipitation pattern and extreme events (Smith and Lenhart, 1996). Therefore, countries may need to plan adaptation strategies for both drought and flooding conditions (Smith and Lenhart, 1996).

2.7 Global Environmental Change and Human Security

Some of the significant threats of climate variability to a region probably will be an increased incidence of storm events, changes in rainfall patterns, effects upon soil moisture budgets and shifts in wind pattern (Cocklin, 1999). The social construction of environmental threats, the specific nature of resource control and ownership, the aspirations of people, systems of governance, including those of tribal leadership, and the cultural meanings attached to the environment are important considerations of environmental change (Cocklin, 1999). Women in poorer countries, for example, bear the effects of environmental change more severely than women living in wealthier countries (Rahman, 2003). Poorer women in rich countries, however, are still more vulnerable to environmental change than relatively wealthier women living in the same area (Rahman,

2003). For instance, a hurricane or flood that leaves two women homeless in the same city will have more impact on a woman without home or health insurance. While episodic changes in the environment leave women especially vulnerable and rapidly diminish their abilities to resist and control such change, it is the everyday dimension of environmental change that is most visibly imprinted onto the lives of women in the South (Rahman, 2003). This is not to say that one dimension of environmental change has more impact than the other, but rather that the effects and responses of women and men to those effects are of a different magnitude and scope (Rahman, 2003).

In India, for example, poor rural women gather most of their resources for household activities from common lands and so are left more vulnerable to resource depletion (Rahman, 2003). Inequality in men and women's access to private property resources is one reason for women's dependency on common resources (Rahman, 2003). Productive resources, such as agricultural land, are largely in the hands of men, as is the income associated with its yield (Rahman, 2003). The decline of forests and other common resources may lead to the lengthening of a woman's working day, already averaging 10 to 12 hours (Agarwal, 1999). Women are more vulnerable to food shortages that may occur indirectly as a result of degradation or state appropriation of resources, and directly due to the intra-household system of food distribution, which often systemically disadvantages female children and women (Ker Conway & Garb, 1999; Rahman, 2003). Women are also more exposed to physical and health hazards due to the nature of their daily tasks and have less access to health care facilities (Rahman, 2003).

The research in India on human security has concluded that people's responses to environmental change, and specifically to degradation, "need to be understood in the context of their material reality, their everyday interactions with nature, and their dependence on it for survival" (Agarwal, 1999: 17). Gender-specific observations suggest that the response of men and women to environmental change may be traced to a gender division of labour, property, and power, and are generally structured by the way productive and reproductive work is organized, not only to gender, but also class, race, and caste (Rahman, 2003).

2.8 Climate variability and Social Resilience

Longer-term perspectives on development and assessments of the set of changing adaptive strategies used by individuals and households enable a more sensitised and realistic understanding of how households live in semi-arid lands (Scoones, 1995; Vogel, 1995). A livelihood is sustainable when it can cope with or be resilient in the face of shocks and stresses, maintaining its capabilities and assets while the natural resource base is not undermined (Scoones, 1995). "To understand and measure vulnerability, particularly during times of food stress and in extreme cases such as famine, it is important to ascertain what factors are constraining or enabling people from gaining access to food by local population"(Vogel and Smith, 2002: 155). In order to determine these factors and other levels of insecurity, indicators of the food balance and the food economy in a household and community should be assessed (Vogel and Smith, 2002).

Assessments of coping and adaptation as well as attempts to increase resilience in arid ecosystems have usually shown that these activities are variable in both time and space (Watts, 1983). Research in Kalahari dry land region has shown that only the most successful households (those with social resilience to environmental change) diversified their portfolio of productive activities (Vogel and Smith, 2002). The poorest, however, with the least resilient cohort of households did not engage nor diversify their portfolio of productive activities rather they rely on informal transfers of resources, as they lack the resources and capacity to do so (Smith, 2001 and Vogel and Smith, 2002). "Social resilience to environmental change is therefore stratified within communities by the disparate ways in which individual households construct their livelihoods from their own particular set of capabilities, access to resources, constraints, and local environmental situations" (Vogel and Smith, 2002: 159). Therefore, dependence on wages, gathering and processing of natural resources for sale, liquidation of assets and the mobilization of social networks, and migration to produce alternative sources of income are some of the ways that people manage and live with changes in the environment (Corbett, 1988; Watts, 1983; Mortimore, 1998; and Vogel and Smith, 2002). Having briefly reviewed some of the relevant literatures to this research, attention is now focused on the conceptual framework.

2.10 CONCEPTUAL FRAMEWORK

2.11 Vulnerability

The study of the vulnerability of human and natural systems to climate variability and of their ability to adapt to changes in climate hazards is a relatively new field of research. Research on global environmental change has significantly improved our understanding of the structure and function of the biosphere and the human activities. The emergence of sustainability science builds toward an understanding of the human – environment condition with the dual objective of meeting the needs of society while sustaining the life support system of the planet (Turner, *et al.,* 2003). The vulnerability of coupled human – environment system is one of the central focuses of this research. One needs a clear understanding of conceptual frameworks that account for the vulnerability of coupled human-environment systems with diverse and complex linkages. The concept of vulnerability varies from one author to another, and also from one discipline to the other. There is no consensus as to its precise meaning. For instance, social scientists view vulnerability as that which represents the set of socio-economic factors that determine people's ability to cope with stress or change (Allen, 2003 quoted in Adger *et al*., 2004), while climate scientists view vulnerability in terms of the likelihood of occurrence and impacts of weather and climate related events (Nicholls *et al.,* 1999 quoted in Adger *et al.,* 2004).

IPCC Third Assessment Report has two definitions of vulnerability. In the first definition, vulnerability is defined as "the degree to which a system is susceptible to or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC, 2001: 995). The second definition, describes vulnerability as "the degree to which a system is susceptible to injury, damage, or harm (one part-the problematic or detrimental part-of sensitivity)". Sensitivity is in turn described as the "degree to which a system is affected by or responsive to climate stimuli" (IPCC, 2001: 894).

The two definitions of vulnerability by IPCC above, however, are very different, and are not consistent. The first definition looks at vulnerability of a system as a function of its sensitivity while the second definition views vulnerability as a subset of sensitivity. Vulnerability in the second definition is a subset of one of the determinants of vulnerability in the first definition, hence making the two definitions contradictory, provided they are assumed to be describing the same vulnerability. Other definitions of vulnerability proffered are "the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor" Turner, *et al*., (2003: 1). Vogel (2001: 2) describes vulnerability as "a multi-layered and multi-dimensional social space defined by determinate political, economic and institutional capacities of people in specific places at specific times". Vulnerability or vulnerable groups implies some form of external dimension that may increasingly predispose people to risk and as well heighten their vulnerability (Vogel, 2001).

Looking at vulnerability from the food security point of view, FAO (1999), for example, defined vulnerability as "the presence of factors that place people at risk of becoming food insecure or malnourished". Also, from a natural hazards perspective, Blaikie *et al.* (1994: 78) defined vulnerability as "the characteristics of a person or group in terms of their capacity to cope with, resist and recover from the impact of a natural hazard". By this definition households that have access to resources and social networks are less vulnerable. Though such households may experience greater losses (in absolute terms) than the poor, they are more resilient in that they recover more quickly from a stress (Blaikie *et al*., 1994).

Definitions of vulnerability in the climate literature tend to fall into two categories (Brooks, 2003), which includes those viewing vulnerability in terms of the amount of (potential) damage caused to a system by a particular climate related event or hazard (Jones and Boer, 2003) and those viewing vulnerability as a state that exists within a system before it encounters a hazard event (Allen, 2003). The former view has arisen from approach-based assessments of hazard and their impacts, in which the role of human

systems in mediating the outcomes of hazard events is downplayed or neglected (Brooks, 2003). Climate variability impacts studies have typically examined factors such as increases in the number of people at risk of flooding based on projections of sea level rise (Nicholls *et al*., 1999), and have focused on human exposure to hazard rather than on the ability of people to cope with hazards once they occur (Brooks, 2003). The hazard and impacts views the vulnerability of human system as determined by the nature of the physical hazards to which it is exposed, the likelihood or frequency of occurrence of the hazards, the extent of human exposure to hazard, and the system's sensitivity to the impacts of the hazards (Brooks, 2003).

Biophysical vulnerability is concerned with the ultimate impacts of hazard event, and is often viewed in terms of the amount of damage experienced by a system as a result of an encounter with a hazard (Adger and Kelly, 1999). Jones and Boer (2003) describe biophysical vulnerability as that measured by indicators such as monetary cost, human mortality, production cost, and ecosystem damage. However, these are indicators of outcome rather than indicators of the state of a system prior to occurrence of a hazard event. According to Allen, (2003) "the view of vulnerability as a state (i.e. as a variable describing the internal state of a system) has arisen from studies of the structural factors that make human societies and communities susceptible to damage from external hazard", as cited in Brooks, (2003: 4). Vulnerability is something that exists within systems independently of external hazards. For many human systems, vulnerability is viewed as an inherent property of a system arising from its internal characteristics (Adger, 1999; Adger and Kelly, 1999), which is referred to as "social vulnerability".

Social vulnerability is determined by factors such as poverty and inequality, marginalization, food entitlements access to insurance and housing quality (Blaikie *et al*., 1994; Adger and Kelly, 1999; Cross, 2001). Hence, it is the interaction of hazard with social vulnerability that produces an outcome, generally measured in terms of physical or economic damage or human mortality and morbidity (Brooks and Adger, 2003 as cited in Brooks, 2003). Therefore, social vulnerability may be viewed as one of the determinants of biophysical vulnerability. Brooks (2003) argues that the nature of social vulnerability

will depend on the nature of the hazard to which the human system in question is exposed. Social vulnerability is not a function of hazard severity or probability of occurrence, but certain properties of a system, which will make it more vulnerable to certain types of hazard than others (Brooks, 2003). For instance quality of housing will be an important determinant of community's (social) vulnerability to flood or windstorm, but is less likely to influence its vulnerability to drought Therefore, certain factors such as poverty, inequality, health, access to resources and social status referred to as generic determinants of vulnerability, are likely to determine the vulnerability of communities and individuals, (Brooks, 2003). Other situations such as dwellings in relation to river flood plains or low-lying coastal areas, however, are determinants that are specific to a particular hazard, including for example, flooding and storm surges. Biophysical vulnerability is a function of the frequency and severity (or probability of occurrence) of a given type of hazard, while social or inherent vulnerability is not (Brooks, 2003). Therefore a hazard may cause no damage if it occurs in an unpopulated area or in a region where human systems are well adapted to cope with it (Brooks, 2003). Having examined some of the discussions of vulnerability, attention now shift to examine the various factors that determines local adaptive capacity.

2.12 Adaptation and adaptive capacity

There are several definitions of adaptation that exist in the climate literature. IPCC describes adaptation as "adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts" (IPCC, 2001: 881). Burton (1992: 22) defined adaptation to climate as "the process through which people reduce the adverse effects of climate on their health and well being, and take advantage of the opportunities that the climatic environment provides". Adaptation is an adjustment to enhance the vulnerability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events as well as longer-term climate variability (Smit *et al* 2000: 239). Also, Olumos, (2001: 5), defined adaptation as "any adjustment, whether passive, reactive or anticipatory, that is proposed as means for ameliorating the anticipated adverse consequences associated with climate variability". Smit *et al* (1996) defined adaptation as "an adjustment in behaviour or

economic structure that reduces the vulnerability of society to changes in the climate system", (cited in Olumos 2001: 5).

Adaptation has the potential to reduce adverse impacts of climate variability and to enhance beneficial impacts, but will incur costs and will not prevent all damages (IPCC, 2001). IPCC Third Assessment Report states that human and natural systems will, to some extent, adapt autonomously and that planned adaptation can supplement autonomous adaptation (IPCC, 2001). "Options and incentives, however, are greater for adaptation of human systems than for adaptation to protect natural systems" (IPCC. 2001: 6-8). The propensity of systems (e.g., socio- economic systems) to adapt is influenced by certain system characteristics that have been called "determinants of adaptation" in the literature (Smit *et al*., 2000). These include sensitivity, vulnerability, resilience, susceptibility and adaptive capacity (Smit *et al*., 2000).

The term adaptive capacity has many definitions. "Adaptive capacity may be described as the ability or capacity of a system to modify or change its characteristics or behaviour so as to cope better with existing or anticipated external stresses" (Adger *et al.,* 2004: 135). Therefore, society has inherent capacities to adapt to change. Burton et al., (2002) argue that the capacities are bound up in the ability of society to act collectively. Individuals, groups within society, organizations and governments on behalf of society, make decisions on adaptation (Burton *et al*., 2002). "The examination of the social dynamics and outcomes of adaptation moves beyond simply accounting for the economic costs and benefits of adaptation to climate variability" (Adger *et al*., 2004: 137). This research also identified the nature of the human-environment interactions, especially the role of social capital in adaptation processes. Local capacity includes the networks and relationships between individuals and social groups that facilitate the economic well-being and security (Adger *et al*., 2004). Research carried out in the coastal environments, shows that coastal urban communities are particularly at risk to climate variability hence, social capital is an important element for coping with climate variability and hazards in recent time. Tompkins and Adger (2003), for example, carried research in the Caribbean coastal area, and showed that communities find strategies to manage risks through strategic and

local networks and interactions. Detailed investigations of social capital illustrate explanations of how individuals use their relationships to other actors in societies for their own and for the collective good, both in material terms and wider spiritual benefits (Adger *et al.*, 2004).

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The concept of vulnerability varies from one author to another and also from one discipline to the other. There is no consensus as to its precise meaning. The definition of vulnerability is essentially determined by the internal properties of a system. Certain factors will make a system particularly vulnerable to specific types of hazard. Other factors might mean, however, that a system has a high capacity to adapt to some hazards but not others. Consequently, the factors that make a system vulnerable to hazard will depend on the nature of the system and the type of hazard in question.

Therefore, understanding the impact of climate on a population is the best way to identifying the most effective means of adaptation to such impacts. Consequently, development has to be based on understanding the existing and future vulnerabilities to climate variability. As the research unfolds, climate and socio-economic factors will be demonstrated as being the combined causative factors of vulnerability to floods. Various climatic variables and socio-economic elements will be investigated in terms of their contribution to vulnerability to floods. In chapter 3, the background to the study and methods are examined. An alternative approach to the conventional method of flood impact assessment is employed to explore the fundamental aspect of human vulnerability to climate variability.