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ORIGINAL ARTICLE

The rains are disappointing us: dynamic vulnerability and adaptation to multiple stressors in the Afram Plains, Ghana

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Abstract This paper builds on work on the dynamics of vulnerability and multiple stressors through a case study in the Afram Plains of the Eastern region in Ghana. A vulnerability framework is applied in the community of Mimkyemfre to identify and explain the multiple underlying political, socioeconomic and environmental forces that influence the ways in which people are exposed and sensitive to climate, and their capacities to adapt to changing conditions. The results of the study indicate that the community experiences a range of biophysical and socioeconomic conditions that contribute to its vulnerability. Vulnerability was found to change over time and in some cases was cyclical, in that certain actions taken for the purposes of adaptation were found to exacerbate existing vulnerabilities. Processes of vulnerability were also found to occur at several scales and were experienced unevenly at the community level. The findings of this assessment have important implications for the design and implementation of successful adaptation initiatives, both in Africa and elsewhere. In particular, they demonstrate the need to understand the social, economic and institutional challenges to development as a basis for any contemplation of adaptation to climate change.

Keywords Adaptation · Afram plains · Africa · Agriculture · Community · Ghana · Food security · Water · Vulnerability

1 Introduction

Climate change is a serious global challenge, with far-reaching effects expected around the world. The manifestations of climate change, ranging from sea level rise to changes in precipitation and the distribution of droughts and cyclones will vary across time and space, interacting with varying socioeconomic systems and local livelihoods to form an uneven

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mosaic of vulnerability (Adger 1999; Handmer et al. 1999; Turner et al. 2003; Smit and Wandel 2006). West Africa is one of the regions expected to be particularly sensitive to climate change, and is in need of practical means for reducing its vulnerability to its associated effects (Downing et al. 1997; Huq et al. 2003; Davidson et al. 2003; Orindi and Murray 2005; Boko et al. 2007). Heavily dependent upon agriculture, Western African countries are projected to experience increases in temperature, altered rainfall patterns, changes in growing seasons and incidence of drought, affecting yields and the availability of already scarce water resources (Watson et al. 1998; Boko et al. 2007). Several parts of the region are also characterized by limited social, political, technical and other resources to draw upon to combat issues of scarcity and poverty, constraining the ability to adapt to changing conditions (Downing et al. 1997; Ikeme 2003; Dixon et al. 2003).

To date, research on the vulnerability of human systems to climate change has largely addressed the expected impacts of climatic change on national, regional or sectoral scales, and the broad types of adaptations that could be employed to mitigate their effects (O'Brien et al. 2004a, Adger et al. 2007). These climate change impact assessments focus on climate scenarios in order to assess the severity of climate change and to identify sectors and areas where impacts of modeled climate variables are expected to be significant, suggesting areas for adaptation. Recent work on adaptation has employed vulnerability approaches that consider climate together with other biophysical and sociopolitical forces, and examine processes underlying vulnerability and adaptation at smaller scales and over time (Brooks 2003; Füssel and Klein 2006). Their contribution is less to assess impacts of climate change and more to understand how societies are susceptible to climate change in order to guide adaptation initiatives. To identify and document the processes that occur on a local level, participatory, "bottom–up" methods are increasingly being employed, involving decision-makers in communities and societies (Yamin et al. 2005; Smit and Wandel 2006; van Aalst et al. 2008). Among the insights from this work on vulnerability is that communities are susceptible to multiple stressors, and climatic stimuli are experienced as a part of a dynamic environment.

This paper builds on work addressing the dynamics of vulnerability and multiple stressors through a case study in the Afram Plains (recently renamed the Kwahu North district) of the Eastern region in Ghana. With over 60% of its population involved in small-scale agriculture, past and present conditions of drought and climatic variability are already affecting the ability of the region's many subsistence agriculturalists to effectively sustain production and livelihoods. In light of the ongoing macroeconomic and socio-political decisions that shape the lives of people throughout the district, environmental changes will have increasing implications for food security, poverty, and the sustainability of local livelihoods. A vulnerability framework is employed in the community of Mimkyemfre to identify and explain the multiple underlying political, socioeconomic and environmental forces that influence the ways in which people are exposed and sensitive to climate, and their capacities to adapt to changing conditions. Factors contributing to vulnerability are not assumed *a priori*, but are identified on the basis of people's experiences, allowing for differentiated vulnerabilities within the community.

The paper has two broad aims. The first is to contribute to the understanding and conceptualization of vulnerability in the climate change field by demonstrating how some widely accepted models apply in a particular community. The second aim is to contribute to practical efforts at enhancing adaptive capacity in the face of changing climate and other conditions, both in the study area and elsewhere, by illustrating the sorts of conditions into which any climate adaptation program would have to work. Beyond this introduction, this paper begins with a brief review of some of the work in the climate change field that has

advanced the concept of vulnerability and its applications. Following this review, the conceptual framework and analytical approach used in this study are described. The results of the case study are then discussed, along with implications for vulnerability assessments in other contexts.

2 Vulnerability to climate change

While initial models of vulnerability to environmental change tended to focus on either the nature of the physical hazard or the inherent societal characteristics, more recent conceptualizations of vulnerability recognize the interaction of social and biophysical forces (Füssel 2005; Adger 2006; Smit and Wandel 2006). The "disaster pressure and release" model (Blaikie et al. 1994) proposed that natural disasters are the result of the intersection of two processes: those generating the inherent vulnerability of a society, and those leading to the physical exposure to hazards. The "hazards of place" model (Cutter 1996) also considered vulnerability as a combination of biophysical risk and the social characteristics that render a society cognizant of and susceptible and able to respond to that risk within a specific place, highlighting the location and context specificity of vulnerability. The "social amplification of risk" framework (SARF) originally developed by Kasperson et al. (1988) examines biophysical risks and the ways in which they may be amplified or attenuated depending on how they are generated, received, interpreted and communicated. This model examines the social qualities, values and institutions that may either trigger or hinder the experience or management of a risk (Pidgeon et al. 2003).

More recently, Turner et al. (2003) employ the framework of "coupled human-environment systems" to explain the multiple and complex processes of vulnerability. Using the concepts of exposure, sensitivity and resilience, the model presents the linkages between human and physical systems, the stresses that emerge from these linkages, and the processes of vulnerability within these, distinguishing the multiple interacting forces that operate on local, regional and global scales. In the climate change context, Smit and Pilifosova (2003) conceptualize vulnerability of a social system to be a function of the exposure-sensitivity of the system to environmental stimuli and the adaptive capacity of the system. Their formulation indicates that the components of vulnerability vary over systems and over time. The Intergovernmental Panel on Climate Change (2007) defines vulnerability as: "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes". Vulnerability is expressed as the function of a system's exposure and sensitivity to climate stimuli, and its adaptive capacity.

Though most work in the climate adaptation field is broadly consistent with this definition, there are many variations in its application. A common approach in the climate change field has been to consider vulnerability as the residual impact of specified changes in climate that remain after assumed adaptations have moderated their initial estimated effects or impacts. Sometimes termed the "impact" or "end-point" approach, this type of work focuses on future temperature norms from climate change scenarios and their impacts at broad scales (Kelly and Adger 2000; O'Brien et al. 2004a). Applications of this approach in Sub-Saharan Africa have yielded insights into the effects of expected changes in temperature, precipitation and the frequency of extreme events on a range of sectors including water management, agriculture, and health (Jones and Thornton 2003; Arnell 2006; McMichael et al. 2006; Thornton et al. 2006; Boko et al. 2007). For example, models indicate that climate change will increase water stress for several African countries,

particularly given existing patterns of water use and population increases (Ashton 2002; Boko et al. 2007). Climate scenarios have been used to project various changes in the agricultural sector, especially small-scale farming, as increased temperatures and changes in rainfall alter regional growing seasons, the extent of suitable rain-fed land, and overall crop productivity (Agoumi 2003; Thornton et al. 2006).

Analyses have also examined projected climate change conjointly with other large-scale processes or forces in order to assess the combined effect of broad stresses on nations, regions, sectors and communities (Adger 1999; Yohe and Tol 2002; O'Brien et al. 2004b). O'Brien and Leichenko (2000) use the term "double exposure" to refer to the effects of climate change together with the consequences of globalization on human and ecological systems, while others have explored the role of "multiple exposures" (Belliveau et al. 2006). These ideas have been used in vulnerability assessments in a range of contexts; applications in Sub-Saharan Africa include work by Reid and Vogel (2006) and Tschakert (2007), who examine the multiple forces and phenomena acting on rural, resource-dependent communities in South Africa and the Sahel, respectively. In these assessments, climatic conditions are noted as one of several types of stresses experienced by community members that range from poor health and unemployment to the absence of effective or appropriate institutional support.

An important development in vulnerability research that is aimed at contributing to practical adaptation initiatives is the recognition of the need to start with the stakeholders to identify (rather than assume *a priori*) the attributes of a changing environment (including climate) that are important for the livelihoods and lives in the community, as well as the various other stresses and conditions that shape exposures, sensitivities and adaptive capacities (Füssel and Klein 2006; Smit and Wandel 2006). The empirical work on multiple stresses has identified combinations of social factors and environmental risks that explain vulnerability as it is evident at the level of communities (Bohle et al. 1994; Adger 1999; Handmer et al. 1999; Ford and Smit 2004). Analyses of actual adaptation processes tend to focus on local or community scales, and the factors and processes related to vulnerability are commonly identified using community-based data collection methods. These studies suggest that an effective, practical means of adapting to climate change is to "mainstream" it into more on-going development activities (resource management, livelihoods, food security or risk management) so as to address the existing processes and conditions that give rise to vulnerability.

Other work in the climate change field has focused on what has been termed "dynamic vulnerability", which recognizes vulnerability as a process in a constant state of change (Turner et al. 2003; Leichenko and O'Brien 2002; Luers 2005). Belliveau et al. (2006), distinguish dynamic vulnerability from multiple stresses or exposures to illustrate the non-static nature of farming systems and the exposures to which they are sensitive, incorporating a range of external biophysical, social, political and economic stimuli. Similarly, Eriksen et al. (2005) identify the interaction of constantly changing social and political processes as the context within which farming communities in East Africa respond to changes in the physical environment. The idea of dynamism in these and other works often refers not only to changes in various environments and the effect of these changes on a system's vulnerability, but also to the potential for the responses of the system to, in turn, reduce or enhance its own vulnerability. This idea of feedback, in which adaptations that are made to certain exposures may actually give rise to other possible exposures or sensitivities, is explored by authors including Turner et al. (2003) and McLeman and Smit (2006).

In summary, research on practical adaptations to effectively address the vulnerability of people to climate change has recognized the need to identify the factors in addition to

climate that contribute to vulnerability, including the multiple forces and dynamic processes that occur at both local and broader scales. The participation of affected communities in the assessment process is important for the accurate identification of the forces that are directly relevant to people and their livelihoods.

This study in the Afram Plains was guided by a general model of vulnerability that draws on the frameworks of Turner et al. (2003), Adger (2006) and Smit and Wandel (2006) (Fig. 1) and a community-based analytical approach broadly consistent with that of Lim and Spanger-Siegfried (2005) and Schröter et al. (2005). The model recognizes that the vulnerability of people in a particular community (local scale) will reflect the interaction of biophysical conditions (including climate change) and socioeconomic conditions, both sets of which will have manifestations at scales from global to local, and both of which are dynamic. Figure 1 does not attempt to represent all factors, interactions, scales or feedbacks, several of which are developed in Turner et al. (2003) and Smit and Wandel (2006). Figure 1 aims to highlight those generic elements of vulnerability that apply at a local scale, reflective of the broader scale processes and relating to adaptation strategies. People's exposures and sensitivities to external conditions are influenced by their occupancy and livelihood characteristics, and the nature and degree to which these are affected by the external stresses. Adaptive capacity (broadly consistent with social resilience) is also reflective of both the natural resource base and the social, economic, cultural and political conditions that facilitate or constrain adaptations to changing environments. Adaptations, or adaptive strategies, employed by individuals or groups are depicted as being mediated through their relative adaptive capacities, indicating that adaptations may or may not be accessed according to the distribution of various types of resources such as physical or social capital, as developed by Adger and Kelly (1999). Components of exposure-sensitivity and adaptive capacity overlap, indicating the interaction and occasional commonality between their respective processes, as developed by Smit and Wandel (2006). Dynamic vulnerability is understood by unraveling the components and processes of exposure-sensitivity and adaptive capacity.

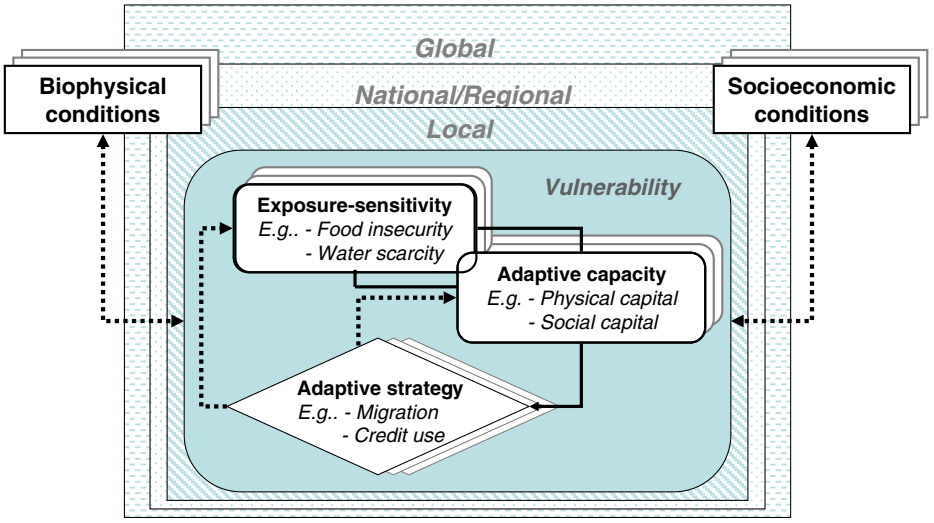

Fig. 1 Conceptual framework on vulnerability

Vulnerability at a local scale is shown as nested within other scales, including the effects that broad-scale forces have on processes of local vulnerability and vice versa. The dynamic nature of vulnerability is indicated by the layers of the components of vulnerability and of the interacting biophysical and socioeconomic forces. Figure 1 also indicates potential feedback between adaptation activities and elements of vulnerability.

This model of vulnerability was used as a guiding framework for the empirical assessment of the vulnerability of the case study community of Mimkyemfre in the Afram Plains (Kwahu North) district of Ghana. Current exposure-sensitivities, adaptive strategies and adaptive capacities of the community are documented and explained in order to provide a basis for understanding vulnerability to future changes in climate and other environments. These were determined using a community-based approach similar to those used by Burton et al. (2002), Ford and Smit (2004) and Schröter et al. (2005), in which the factors and forces relevant to the community vulnerability were sought via primary and secondary sources. A key element of the approach is to engage community members as necessary sources of information on the conditions to which they are exposed and how they are sensitive, the adaptive strategies they have employed, and the conditions that constrain or facilitate these strategies. This detailed analysis of current vulnerability identifies opportunities for adaptive interventions or initiatives, and provides a basis for estimating future vulnerabilities by extending processes of exposure-sensitivity and adaptive capacity, and by incorporating projections of future climate change and other conditions.

3 Case study: Mimkyemfre, Afram Plains

The Afram Plains district is located in the Eastern Region of Ghana, bounded to the south and east by Lake Volta since the creation of the Akosombo Dam in 1964 (Fig. 2). The dam's construction necessitated the relocation of an estimated 80,000 people from 740 villages along the banks of the Volta River into 52 government-sponsored townships around the newly-created lake. Without any overland transportation routes from the north or west, and until recently very little development activity, the district has since become effectively isolated from the rest of the country and has been constrained in the flows of people, goods, technology and information in and out of the district.

While the Lake and its tributaries comprise the majority of surface waters in the area, several smaller and often ephemeral tributaries also cross the area near to which several of the resettlement communities, including Mimkyemfre, are located. The community of Mimkyemfre is a small resettlement township located 16km south of the district capital of Donkorkrom (Fig. 2). The community is situated in an area of considerable intra-annual variability of precipitation (Fig. 3) in a zone of transition between forest and Guinea savannah, characterized by a mix of deciduous tree species and short to medium species of grass. While several of the original settlers relied on fishing as the predominant source of livelihood, the location of the resettlement communities further away from a major body of water prompted a shift towards a mix of subsistence agriculture, fishing, and increasingly, charcoal production as principal sources of local income. Over the last several decades, the initial settler population of 1,639 has dwindled to less than 950, principally as a result of problems that arose out of the resettlement process, including a lack of access to the lake for fishing and local water sources. As many of the original settlers' livelihoods depended primarily on fishing, several households left in order to live closer to year-round fishing grounds, while others chose to remain at the resettlement. Similarly, inadequate water supplies prompted many to return to the banks of the newly-formed lake.

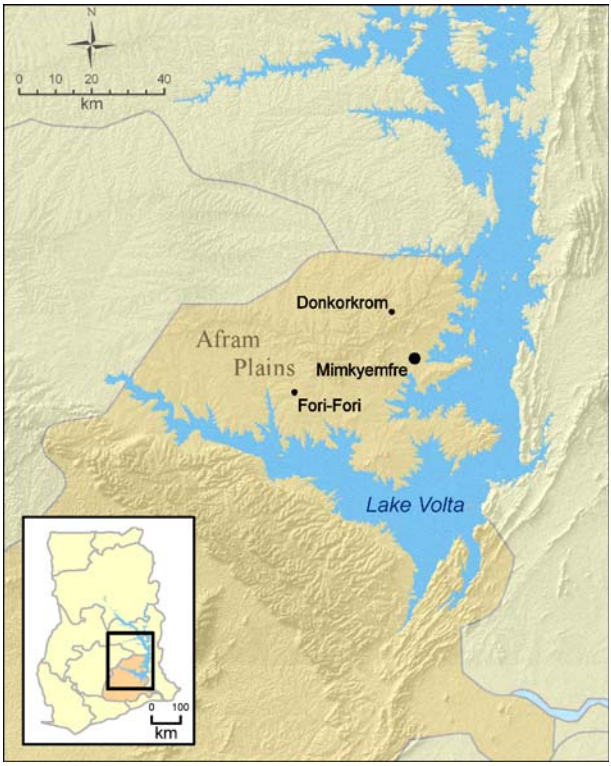

Fig. 2 Location of Mimkyemfre, Ghana (Vector data used under license from ESRI Inc. © 2006)

The vulnerability assessment of Mimkyemfre was conducted in order to determine community-relevant exposure-sensitivities and to characterize current adaptations as a basis for estimating adaptive capacities under future conditions. Most of the primary data were derived from 22 semi-structured, in-depth interviews with 11 male and 11 female

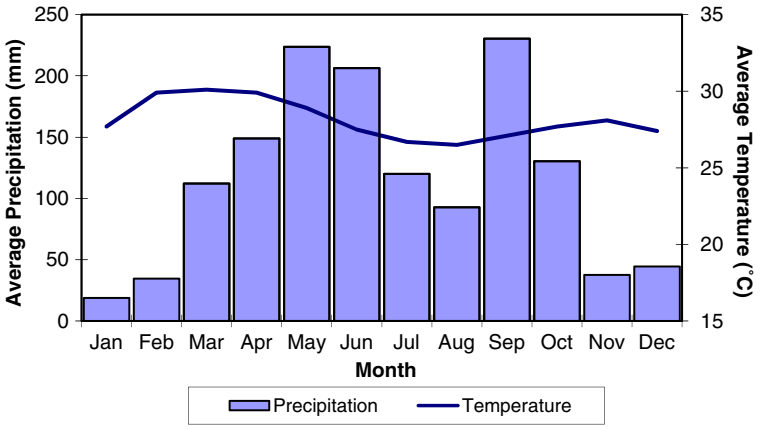

Fig. 3 Average monthly precipitation and temperature for Fori-Fori (30 km from Mimkyemfre), 1997–2007 (Source data: Ghana Meteorological Service)

community members, who were asked to describe and explain in local terminology the various exposure-sensitivities, adaptations and adaptive capacities of importance to them. The use of semi-structured interviews has been shown to allow for in-depth understanding of pertinent issues in a range of research contexts by guiding conversations along themes of interest to the researcher (Adger and Kelly 1999; Ford and Smit 2004; Ziervogel and Taylor 2008). Interviewees were selected using purposeful and "typical case" sampling methods in order to obtain an illustrative sample of gender and age groups (Bradshaw and Stratford 2000). Members of the community who were engaged in farming or other commonly-practiced activities were included, as were typically marginalized groups such as women and the elderly, to gain insight on different experiences within the community. These community-member interviews were complemented by an additional 22 in-depth interviews with key informants from various governmental and non-governmental institutions in the area for the purposes of obtaining further information on the relevant contributing biophysical/socioeconomic forces, exposure-sensitivities, adaptations, and adaptive capacities in Mimkyemfre. Key informant interviewees were selected based on their expertise on and/or experience with the community and its environment, and ranged from community members to members of relevant institutions, including local NGOs, the Ministry of Food and Agriculture, the National Health Insurance Scheme, the Department of Forestry and several others.

In addition, five focus groups were conducted with members of the community, through which data on the experience of vulnerability by residents engaged in primary livelihood activities were gathered. Information on methods of farming, charcoal production and fishing, the stresses on these livelihoods, and the means for overcoming these stresses was compiled. Focus groups were used to investigate interactions between community members and other aspects of vulnerability that became evident in the group dynamic, an effect often referred to as 'synergism' (Morgan 1996). Participants for focus groups were selected primarily using a combination of purposeful and typical case sampling methods in order to identify members that were representative of the community so as to ensure a typical characterization of the community was obtained. The community-based data collection was complemented by a review of documents and records to extract information on the biophysical and socioeconomic forces contributing to vulnerability. Documents comprised existing studies completed in the area, government reports, climate data, and all other pertinent information. Data from these multiple sources were coded, sorted and analyzed (in part using qualitative data analysis software) according to the themes of the conceptual model of vulnerability in order to identify relevant forces, exposure-sensitivities, adaptations and adaptive capacities experienced at the individual, household and community levels.

3.1 Multiple exposures and scales of vulnerability

The results of the vulnerability assessment in Mimkyemfre indicate that the community is presently experiencing a range of exposure-sensitivities that may be categorized into four principal and interrelated themes: 1) food insecurity, 2) water scarcity, 3) illness and infirmity, and 4) financial insecurity. These were found to have multiple, interrelating forces that act at various scales to form current vulnerability at the community level (Fig. 4). The experience of vulnerability within the community was found to be quite variable, as certain subsets of the community experience stresses differently and have different access to resources to assist them in coping with these stresses. Although the four main dimensions of exposure-sensitivity are interconnected, this section will address each one in turn,

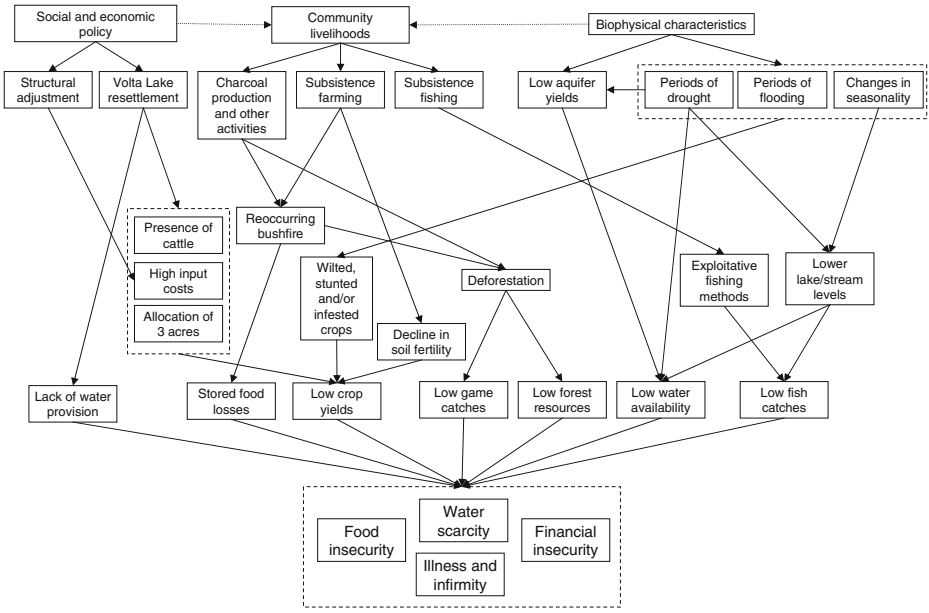

Fig. 4 Processes of exposure-sensitivity in Mimkyemfre, Ghana

including the underlying forces and processes, adaptive strategies employed, and the associated adaptive capacity. These are outlined in Table 1.

The term **food insecurity** here is consistent with that of the FAO (1999), which is the condition of lacking "physical, social and economic access to sufficient, safe and nutritious food that meets…dietary needs and food preferences for an active and healthy life". Food sources in Mimkyemfre, as generally throughout the Afram Plains, are derived principally from subsistence agriculture, supplemented in some households by fishing, and to a lesser degree, hunting and purchased goods. Large-scale socioeconomic factors that affect Mimkyemfre residents' ability to produce sufficient food for the household relate to macroeconomic agricultural policy and the political decisions surrounding the process of resettlement. Prior to relocation, many farmers owned extensive farming operations with some overseeing as many as 20 acres of land. This scale of farming was significantly reduced during resettlement, at which time each household was allotted only three acres of land, limiting the ability of households to cultivate enough to simultaneously feed household members and gain sufficient income. Though farmers are permitted to purchase additional lands, the conditions that have constrained productive agriculture have effectively prevented many from gaining enough income to do so, restricting many to their original three acres. With the implementation of structural adjustment policies and the subsequent removal of input subsidies, the ability of farmers to purchase fertilizers, pesticides and improved seed has also been considerably weakened. Credit shortages have decreased farmers' ability to access inputs, while costs of pesticides and fertilizers has steadily risen (Weissman 1990; Alderman 1996). The result has been the partial or complete abandonment by many Mimkyemfre farmers of the use of inputs that would otherwise assist them in reducing infestation, improving soil fertility, and enhancing overall productivity.

Broad biophysical factors that have contributed to food insecurity arise primarily out of climatic variability and extreme precipitation events that occur frequently throughout the

Table 1 Summary of exposure-sensitivities, adaptive strategies and adaptive capacities experienced in Mimkyemfre

Exposure-sensitivity	Adaptive strategies	Adaptive capacity constraints
Food insecurity	• Changes to farming/fishing	• Low access to physical/financial resources
	• Changes in food consumption	• Poor health
	• Increased reliance on non-farm products	• Family size and composition
	• Increased dependence on social food networks	• Poor access to social networks
Water scarcity	• Walk to lake, rivers to collect water	• Low access to physical/financial resources
	• Use of hand-dug reservoirs	• Poor health
	• Rainwater collection	• Family size and composition
	• Purchase of drinking water	• Poor access to social networks
Illness and infirmity	• Changes in household organization (to compensate for lost labour)	• Low access to physical/financial resources
	• Use of traditional medicines	• Family size and composition
	• Use of local health care providers	
	• National Health Insurance Scheme	
Financial insecurity	• Use of family networks (migration)	• Lack of alternative livelihood options
	• Alternative, non-traditional livelihood activities (*e.g.,* charcoal production, hairdressing, etc.)	• Low access to physical/financial resources
	• Reductions in household expenditure	• Poor health
	• Changes in household labour	• Low education
		• Family size and composition
		• Poor access to social networks

district and across West Africa. Inter- and intra-annual climate variability and uncertainty act as constraints to productive agriculture and thus the availability of a primary source of food, particularly during conditions of drought. Though located in a region of general climatic variability, Mimkyemfre receives less rainfall than proximate communities, attributed in part to the presence of the Kwahu scarp and the resultant rainshadow that is cast over the Plains (Diaw and Schmidt-Kallert 1990). The implications of these conditions of drought, flooding and variability on agriculture ultimately relate to variations in crop yields and hence the principal source of food for the majority of households. Declines and changes in precipitation and their effect on the water levels of Lake Volta and its tributaries have also reduced fish catches by reducing proximate fish populations and bringing submerged trees closer to the surface, snagging nets and creating fewer navigable canoe routes. With the delayed flooding of the adjoining rivers and subsequent lack of riverine fish, fishers are compelled to travel farther to the lake to find adequate fish stocks. Extreme storm events that occur frequently throughout the rainy season also render conditions unsuitable for fishing by upsetting lines set and risking fishers' safety. As fish provide an important source of protein to the diets of community members, these difficulties in accessing increasingly fewer fish pose a challenge to overall food security in Mimkyemfre.

Local-scale processes have also had an impact on food security through ongoing environmental degradation related to bushfires, charcoal production, and the overexploitation of fish and forest resources (Fig. 4). Bushfires are a reoccurring phenomenon in the Afram Plains district, particularly during the Harmattan or periods of drought. Though dry, hot

conditions are the necessary precursors for their existence, and high winds for their rapid expansion, bushfires are not typically naturally-occurring in the study area and are almost invariably initiated by slash-and-burn clearing practices, intentional burning for pasture, and other local activities such as honey-tapping and charcoal production. Bushfires that occur during periods of cultivation put existing crops at risk, and if consumed reduce agricultural productivity. Those that occur during the dry season may threaten post-harvest goods, particularly maize, that are commonly stored in makeshift barns located on the fields. Coupled with charcoal production, bushfires remove local vegetation and remove habitat, which has led to decline in game and other animal populations; several formerly indigenous species, such as antelope and buffalo, are no longer found. Similarly, detrimental fishing practices and the prevalence of fishers in the area is beginning to reduce fish populations in the Lake and its tributaries, limiting catches and increasing the amount of time fishers must spend on the water.

The food insecurity exposure-sensitivity in Mimkyemfre is clearly a reflection of multiple stresses, of which climate factors are a relatively modest force experienced together with political, economic and social conditions (Fig. 4). Generally, adaptive strategies used to cope with food shortages are spontaneous and reactive to changes in environmental and other conditions, and innovative given restrictions in the ability to plan or prepare for these changes. However, some adaptations have become more entrenched within daily activities and are the result of perpetual or reoccurring stresses; for example, farmers may change planting or harvest times based on the onset and duration of the rainy season. Other adaptive strategies include earlier weeding, constructing housing structures or covering soils with grass (to shade crops from the sun and to conserve moisture), hand-watering garden crops, and planting closer to water sources or where the lake has receded. On occasions of complete crop failure, households may change consumption habits by increasing the consumption of stored or purchased foods, increasing the reliance on cassava (a drought-resistant crop that forms the basis for much of the local diet), or increasing the dependence on social food networks (Tab. 1).

The exposure-sensitivity of **water scarcity** is widely experienced throughout the community, also as a result of several interrelated forces (Fig. 4). The failure of large-scale water provision efforts has been at the root of the lack of water in Mimkyemfre, in that water systems provided as a condition of resettlement were initially inadequate, became irreparably damaged in the 1990s and have since been inoperative. Though Mimkyemfre was provided with pumped water that was accessed through four standpipes located around the community, it was known that the supply of groundwater was insufficient to provide residents with a continuous supply of water, and thus the location of the community was set at what was deemed close proximity to the lake (Chambers, 1970; Diaw and Schmidt-Kallert 1990). More recent efforts to provide the community with a more accessible supply of water via boreholes also failed, as of the three that were drilled, one was found to provide water of adequate quality but was low in pressure, while the other two provided water that was both unsatisfactory in quality (appearance, odour and taste), and insufficiently pressurized. This failure may also be partly explained by the underlying geology of the area. While sufficient in meeting minimum requirements for borehole establishment, the middle Voltaian formation underlying the Afram Plains produces a relatively low average borehole yield of roughly 1–3 m 3/h; the resultant success rate of regional boreholes is only 56% (Dapaah-Siakwan and Gyau-Boakye 2000).

Recent explorations by a local NGO have further revealed that borehole water levels throughout the district have been falling since 1990, indicating that groundwater recharge is insufficient in meeting water demand. Low precipitation rates may also be linked to low

recharge rates, rendering the possibility of installing functional boreholes even less likely in the future. As a result, residents seek untreated water from Volta Lake, as well as the ephemeral Kyemfre River and other smaller tributaries to the lake, naturally-occurring and man-made reservoirs, and rainwater (Tab. 1). However, variability in rainfall patterns limits the availability of and access to many surface water sources. Lower lake levels and delayed flooding of rivers force women and children to travel further distances to fetch water, while periods of drought or postponements in the rainy season reduce the opportunities for residents to collect rainwater. Local conflicts over resources with local herdsmen occasionally exacerbate these issues.

The exposure-sensitivity of **illness and infirmity** is related, in part, to the absence of potable water. This, in combination with a general lack of sanitation facilities, has resulted in a number of water-borne diseases spread through contact with or use of untreated water containing parasites and their vectors. Of these, the most common is bilharzias, or *schistosomiasis*; residents often become infected by wading or bathing in the nearby snail-inhabited waters of the lake and streams in order to access the most readily available source of domestic water. Untreated surface waters are also a source for several other forms of water-borne illnesses, including cholera, typhoid, meningitis and several others. Vector-borne diseases (VBD), notably malaria, account for the other illnesses reported in Mimkyemfre, especially in young children who have not yet developed a natural resistance to parasites, and older residents. Residents may also sustain injuries during farming or charcoal production activities, which in some cases have become long-term disabilities. Residents use a combination of reactive adaptive strategies that consist principally of the use of traditional medicines and local health care providers, including informal "chemical sellers", the local clinic and the district hospital (Tab. 1). More recently, the National Health Insurance Scheme that was initiated in 2004 has begun to provide residents with formal health insurance coverage.

A compounding effect of food insecurity, water scarcity and illness is that many residents are susceptible to **financial insecurity**. As farming and fishing provide the livelihood basis for the majority of Mimkyemfre's residents, several households are experiencing difficulty gaining enough income to provide for basic amenities or education. Residents indicated that the declining success of their crops occasionally obliged them to keep what they could harvest for their household needs in lieu of selling them in the market, reducing household income. Those who are dependent on fish catches as a source of income experience the same phenomenon: with smaller catches and smaller fish size, income gained from fishing has declined. However, large-scale processes have also more directly prevented residents from gaining sufficient income to meet household needs. Travel to larger markets in the district capital is time-consuming and expensive, while access to more distant market chains is severely limited by inadequate infrastructure. Transportation means and infrastructure are such that distances between Mimkyemfre and larger markets are too great for the possibility of selling more perishable crops on a larger scale. Additionally, the cost of inputs as a result of structural adjustment has limited farmers' ability to purchase inputs, further constraining their ability to participate in larger-scale agricultural markets. Opportunities for employment or work outside of subsistence agriculture are scarce, limiting residents' ability to seek other sources of income; residents increasingly turn to charcoal production as a means for gaining income, the implications of which are discussed in the next section.

Residents' access to adaptive strategies is mediated by varying adaptive capacities across the community. Adaptive capacity was found to be either constrained or enhanced by a number of issues or assets. The absence of alternative livelihoods and limited access to

financial and thus physical resources have played important roles, in that most residents were unable to find viable alternatives to farming or fishing, limiting their ability to raise household income in the face of difficulties (Tab 1). Low financial resources have limited residents' ability to procure household needs or to invest in agricultural or fishing materials, new income-generating activities or other employment opportunities. Lack of education has also played a role, in that many households are unable to afford further education, limiting employment opportunities. Poor health has constrained residents' ability to procure household needs and find gainful income; similarly, those with limited access to social networks were found to be less able to access food, water and labour. Poor extent and efficiency of services and a lack of much-needed water infrastructure in Mimkyemfre can be in part attributed to a lack of accountability when allocating funds to various projects. Residents' lack of community mobilization and general disinterest in participating in institutional efforts at poverty reduction, while perhaps warranted given low financial resources and service provision effectiveness, may also act as a constraint to adaptation.

Both the experience of exposure-sensitivities and the constraints to accessing different adaptive strategies are unevenly distributed throughout the community, despite general similarities in livelihoods. In Mimkyemfre, women, low-income groups and the elderly were particularly affected by conditions of food, water, and financial insecurity as they were less able to prepare for and respond to changes. In the case of food insecurity, these groups often had less access to cultivable land, or were simply unable to participate in farming or other food production activities. Elderly residents were found to be less physically and financially able to procure sufficient food and water independently, while women were often unable to allocate time or resources away from the home to effectively fulfill household food needs. Illness and infirmity were also found to disproportionately affect very young and elderly residents whose resistance to various illnesses was lower and their exposure at times higher.

3.2 Dynamic vulnerability

The components of vulnerability vary over time as a result of evolving external conditions, changing internal characteristics, and interactions between people and their environment. Processes of adaptation at the community level in Mimkyemfre are not static, but change in reaction to the various stimuli. Considering changes in exposure-sensitivities related to climate, and adaptive strategies in agriculture have reflected alterations in moisture availability from year to year. Depending on climatic conditions, farmers employ strategies for either conserving moisture or coping with its excess. Water collection strategies have also varied according to surface water availability: with heavier rains and subsequently higher river levels, residents are able to collect surface water closer to the village or collect rainwater in lieu of traveling to the lake. Changes in fishing methods have also reflected dynamic lake conditions that have reduced fish populations. As the lake recedes, many fishers travel further into the lake to access fish stocks and often use more intensive harvesting techniques, including the use of nets with smaller mesh sizes or the increase in number of traps set.

Residents' experiences of vulnerability have also changed as a result of broad scale social and economic processes manifesting at local scales. In particular, the process of resettlement in the early 1960s resulted in a shift for many of the original settlers away from commercial fishing or cocoa production towards subsistence farming and fishing as the principal sources of livelihood. This was largely the result of the change in physical location away from areas suitable for cocoa plantations and from the banks of the Volta

River. Clearly, the implications of this development policy and the resettlement process profoundly affect the base vulnerability of Mimkyemfre residents and limit their capacity to deal with additional stresses that may come with climate change. More recently, changes in macroeconomic policy and local development activities have discouraged the use of inputs such as fertilizers and pesticides through higher prices, while simultaneously encouraging the use of certain types of crops that have been deemed marketable and thus preferable over others.

As a part of their dynamic nature, some processes of exposure and adaptation are cyclical in nature and may catalyze further vulnerabilities, in that adaptations may serve to prompt or exacerbate conditions to which community members are sensitive. The production of charcoal, which is being increasingly used as an adaptive strategy for gaining income in response to dwindling incomes from farming and fishing, provides an example of this feedback effect (Fig. 5). Charcoal production is linked to food and financial insecurity through its influence on deforestation and bushfire. Processes of deforestation associated with charcoal production are partially responsible for losses in game species and other forest resources such as medicinal plants that contribute to many households' food and medical supplies. The production of charcoal is also one of the sources of bushfires common throughout the district that frequently result in the loss of large tracts of agricultural land and stored post-harvest goods, lowering household food availability (Fig. 5). Deforestation and bushfire have also been linked to reductions in soil moisture and overall soil fertility through increased erosion and decreases in soil organic material, particularly in incidences of repeated burning (Snyman 2004; Doerr and Cerdà 2005; Vågan et al. 2005). These processes of deforestation, bushfire, and loss of yields and products reduce sources of food and income for residents and have prompted many to seek alternative livelihoods, often in the form of charcoal production itself (Fig. 5). This increasing dependence on charcoal as a primary source of income has consequences for the sustainability of agriculture and thus for the community's vulnerability to changing conditions.

It should be noted that the purpose of Fig. 5 is not to demonstrate the multiple, interrelated processes of vulnerability, but rather to focus on one dynamic, acknowledging that other forces and processes may contribute to it. Of course, declines in soil fertility are

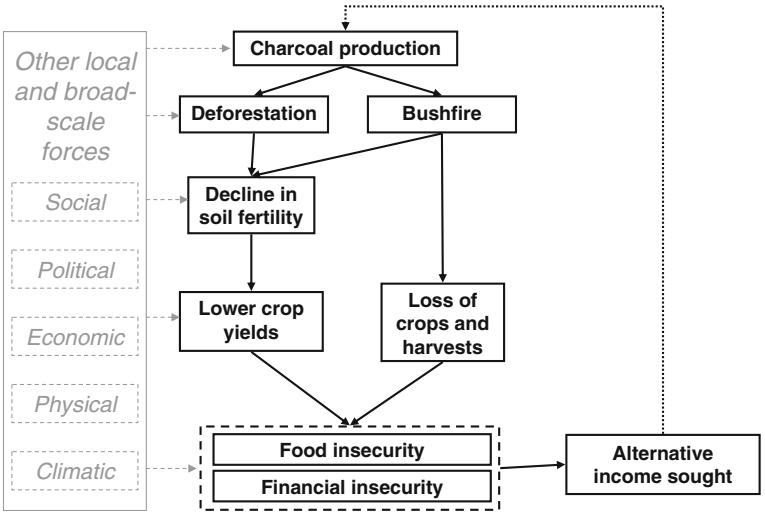

Fig. 5 Charcoal production as an example of positive feedback

by no means the sole contributing factor to low yields or lower food supplies, nor is charcoal production the only force acting on forest resources and soil fertility. Charcoal production is one example of an adaptive strategy that may reduce vulnerability in the short term (*e.g.*, reduction in financial insecurity through charcoal production) but may increase overall vulnerability in the long term (*e.g.*, increased food and financial insecurity through resource degradation). Other adaptive strategies may also have effects on the biophysical (or social, political, or economic) environments at various scales that shape local livelihoods and thus overall vulnerability, and are often employed in response to multiple exposure-sensitivities.

Vulnerabilities (including their exposure-sensitivities and adaptive elements) may manifest differently according to their context and scale. For example, bushfire acts as both a contributing factor to food insecurity at the community level, and as a constraint to effective adaptations by community members and to agricultural extension efforts by local government bodies. This sort of interdependence also applies to illness, as another example, which is considered an exposure-sensitivity to changing conditions, and which also serves to limit residents' ability to adapt to food and financial insecurity.

4 Adaptive capacity under climate change

The processes of vulnerability identified in this study have several implications for efforts and activities designed to promote successful adaptations to future changes in climate. Changes in temperature and the amount and distribution of precipitation have already been observed by residents of Mimkyemfre and several communities across West Africa, and are anticipated to continue. Ghana's Environmental Protection Agency has indicated that over the period of 1961–1990, the country experienced an increase in temperature by 1°C and a reduction in precipitation by 20% (Environmental Protection Agency (EPA) 2001). Estimates of future warming project an additional increase of 0.2°C–0.5°C per decade, with a 2°C–3°C increase overall by 2100 (Hulme et al. 2001; Christensen et al. 2007). While estimates of the amount and distribution of precipitation remain uncertain, interannual variability is expected to increase, with an increase in the intensity of high-rainfall events but an overall decrease in the number of rain days (Hulme et al. 2001; Christensen et al. 2007). Enhanced ENSO-related extreme events, reflected in droughts and floods, are also anticipated (Fig. 6).

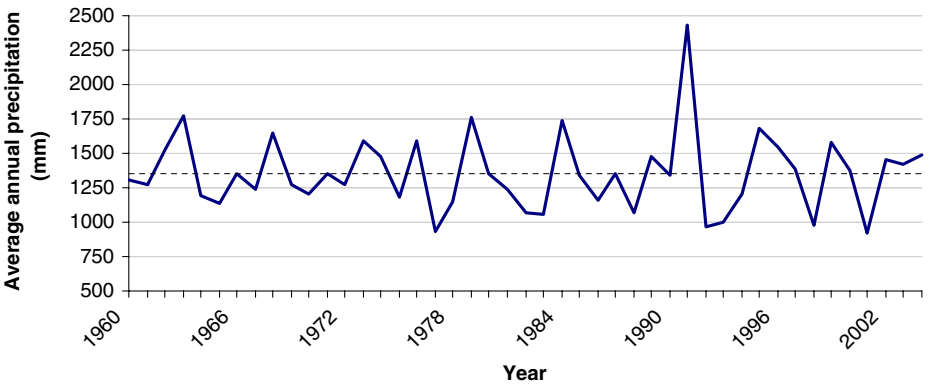

Fig. 6 Interannual variability of precipitation, Kete Krachi (100 km from Mimkyemfre) (Source data: Ghana Meteorological Service)

These changes in climate could have several implications for many communities across the country, and in the case of Mimkyemfre, for the exposure-sensitivities identified in the vulnerability assessment. Increases in temperature and enhanced moisture deficits would increase stresses on crop production and food security. Similarly, increases in interannual variability, periods of drought and periods of flooding and infestation would impact productivity of crops, and could result in complete crop failure (Rosenzweig et al. 2001; Boko et al. 2007). Reductions in surface water and the increased frequency of extreme events would affect fish habitat and stocks, and climate-related changes vegetation would exacerbate stresses on game animals. These changes in agriculture, fisheries and hunting prospects could considerably limit the ability of households to access conventional food sources. The community's vulnerability to potable water scarcity would become more severe with decreases in rainfall and surface water availability, and reductions in groundwater will further constrain plans for pumped water systems. The expected stresses on food and water sources, in combination with changes in the conditions conducive to malarial and other outbreaks, could increase incidence of disease. Changes in exposure-sensitivities with future climate are likely to have detrimental impacts on residents' financial situation and overall well-being as household income sources are reduced.

Of course, changes in climatic conditions will not be experienced in isolation, but together with changes in the political, economic and social conditions within which Mimkyemfre functions. One example of these changes is population growth. At the current rate of growth, the population of the Afram Plains district is projected to increase to roughly five times its present size by the year 2050 (Agriculture and Rural Development Department (OCAR) 2006). In the case of Mimkyemfre, populations may increase further as a result of a planned water system to be installed by the end of 2008, drawing those who migrated closer to the shores of the lake back to the village. Additionally, the frequent migration of youth to city centres may create a higher relative proportion of dependents (very young and elderly residents). While outmigration may reduce some of the stresses on land and water resources, these combined demographic changes will likely put additional stresses on the natural resource base, with implications for the sustainability of local livelihoods (Geist and Lambin 2001; Vorosmarty et al. 2000; Codjoe 2006). Similarly, the macroeconomic environment is not expected to change in ways that will reduce stresses for Mimkyemfre. For example, the ongoing liberalization of the Ghanaian economy will likely continue to expose small-scale farmers and entrepreneurs to global prices and fluctuations, affecting their ability to maintain or improve their livelihood activities and thus diminishing opportunities for maintaining or improving financial security.

These changes in the climatic and other environments clearly present significant constraints on prospects for adaptation. The multiple sources and scales of exposure-sensitivities create a complex process of vulnerability, with various forces acting to constrain adaptive capacity at the local scale. However, there are a number of local, national and international initiatives that may also serve to enhance the capacity to adapt in Mimkyemfre and other communities. If effectively implemented, local government-led programs such as the Afram Plains District Agricultural Development Project (APDADP) could reduce residents' vulnerability through the strengthening of agricultural and other livelihoods. The APDAPD aims to provide communities throughout the district with services such as enhanced access to agricultural inputs, equipment and markets, improved physical infrastructure, and others that combined may improve residents' ability to procure food and financial resources. National-scale programmes such as the Ghana Poverty Reduction Strategy (GPRS II) and aid packages such as the Millennium Challenge Account may also reduce poverty through the enhancement of the agricultural sector, and may

further improve farmers' access to inputs and markets. These poverty reduction efforts may be complemented by a number of climate change adaptation projects that have begun across Sub-Saharan Africa, including those with activities in West Africa such as START and UNITAR's *Advancing Capacity to Support Climate Change Adaptation* (ACCCA), and IDRC's *Climate Change Adaptation Africa* (CCAA).

Regardless of their origins, these programmes and initiatives would substantially benefit from the consideration of the processes of vulnerability, including first the multiple forces and conditions that contribute to overall vulnerability. In Mimkyemfre, exposure-sensitivities were found to have multiple, interrelating forces that ranged from socioeconomic to biophysical. National level political and economic decisions, including the structural adjustment and Volta Lake resettlement programmes, continue to affect residents' ability to procure food, water and financial resources, which is exacerbated by climatic variability and extremes, geologic conditions, and processes of local-scale environmental degradation. These forces have multiple implications at the community scale, often contributing to more than one exposure-sensitivity. For example, climatic variability and extreme events affect crop productivity, fish and game stocks and thus food availability, as well as the availability of surface and groundwater sources. Local efforts to adapt to climate change would have limited effectiveness if the broader conditions for development were not significantly improved.

Processes of vulnerability evolve at a range of scales, with exposures and adaptive capacities the result of phenomena at local (*e.g.*, bushfire), regional (*e.g.*, climatic conditions), national (*e.g.*, resettlement schemes) and even international (*e.g.*, World Bank-inspired macroeconomic policy) levels. Addressing these multi-scalar processes is essential to efforts to reduce exposure-sensitivities and enhance adaptive capacity in communities like Mimkyemfre.

Finally, the dynamic nature of the processes of vulnerability in Mimkyemfre requires the understanding that these are neither static nor necessarily linear. Processes of feedback and return were found in some cases to yield adaptations that are beneficial in the short term, but may be harmful or counter-productive in the longer term. Charcoal production provides a clear example of this dynamic, in that its widespread use as an alternative income source in the face of low agricultural returns serves to diminish local natural resources upon which residents depend for food and income. As a result, attempts to promote adaptations need to take into account the various effects activities may have on other existing or potential exposures-sensitivities or constraints to adaptation.

5 Conclusion

The application of a generic vulnerability framework to the case study in Mimkyemfre, Ghana has revealed some of the complexities of exposure-sensitivities and adaptations, which contribute to our understanding of vulnerability to climate change and which have implications for efforts to reduce the vulnerability of communities in general.

First, the case study demonstrates that vulnerability reflects multiple forces and processes that shape exposure-sensitivities and adaptive capacities, and that adaptation efforts need to be designed for that reality. Initiatives that focus on climate change as the sole (or main) issue of consideration in adaptation may be ineffectual or even maladaptive when the conditions to which people are sensitive are the result of interacting climatic and non-climatic stresses. Adaptation activities will have greater chance of success if they consider the multiple sources of vulnerability and recognize that community-level

adaptations need to be integrated into the realities of community livelihoods and effective development initiatives.

Second, this study has shown that there are considerable limitations to the adaptive capacity of individuals and communities, as the conditions which constrain their opportunities are determined beyond the scale of their influence. Impact assessments that simply assume people will adapt to climate change are likely to overlook important facets of vulnerability. The processes that influence vulnerability within a community may have contributing forces at several scales, indicating that efforts to reduce vulnerability would benefit from activities that address issues beyond the local area. Adaptation initiatives could further benefit from acknowledging the variable experiences of vulnerability even within a single community, in that certain subsets of a community may experience vulnerability more or less acutely. By targeting groups that require particular or additional assistance to current stresses, these groups may have greater success in adapting to future changes in climate

Finally, there is a need to acknowledge that the processes of vulnerability are dynamic and involve complex relationships, often including feedbacks among multiple stresses, exposure-sensitivities and responses. The adaptive strategies employed in response to one or more exposure-sensitivities may in turn act as catalysts for further exposure; these responses may have different effects on varying scales, and will require close attention when promoting activities for the purposes of enhancing adaptive capacity.

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