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Climate Variability and Change: Implications for Household Food Security[1]

Gina Ziervogel,[2] Anthony Nyong,[3] Balgis Osman,[4] Cecilia Conde,[5] Sergio Cortés, and Tom Downing[6]

1. Introduction

Food security, which became a catch-phrase in the mid-1990s, can be defined as the success of local livelihoods to guarantee access to sufficient food at the household level (Devereaux and Maxwell, 2001). The failure of early solutions to the problem of food insecurity in the 1970s and 1980s was largely attributed to their technological bias, stressing production rather than equitable distribution, access, affordability, and utilization. Since then, it has become clear that food security revolves around complex issues that encompass a wide range of interrelated environmental (and climatological), economic, social, and political factors. Addressing food security, therefore, requires an integrated approach (as highlighted in the introduction of this volume) and challenges many regions' ability to address food security adequately (Vogel and Smith, 2002; Clover, 2003).

Early models projecting world food demand and supplies into the twenty-first century generally showed that global food supplies will match or exceed global food demand at least within the next two to three decades (Devereux and Edwards, 2004). One shortcoming of these models is that the scales of the models are very coarse and conceal regional disparities that are a major concern for already food-insecure regions (Stephen and Downing, 2001). Another shortcoming is that the models paid little or no attention to climate variability and change. Climate variability and change are a major threat to food security in many regions of the developing world, which are largely dependent on rain-fed and labor-intensive agricultural production (Parry et al., 1999, 2004; Döös and Shaw, 1999; IPCC, 2001a).

Although there is research on the impact of climate on food production, there is limited understanding of how climate variability currently impacts food systems and associated livelihoods (Downing, 2002; Ziervogel and Calder, 2003). This needs to be

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better understood before assessing the impact of climate change on food security. Variability is a measure of the frequency distribution of the value of climate variables and their range over a given time period. Temperature and precipitation are the climate variables most critical to measure with regard to food systems. Not only does the range between high and low values matter, but also the frequency at which these extremes occur and the intensity of the events. Our focus in this paper is on the impact of below-normal rainfall and drought on food security. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001b) projects that areas that are currently dry might experience an average increased dryness with global warming. It is important to note that with a climate that is warmer on average, even if there is no change in the amplitude of El Niño, the risk of droughts and floods that occur with El Niño will increase. In southern Africa, there is evidence that the drought experienced during the second half of the twentieth century has been influenced by greenhouse gases, and drying trends are projected to continue (Hoerling et al, in press). Variability is also expected to increase with more rain falling in intense-rainfall events, larger year-to-year variations in precipitation in areas where increased mean precipitation is projected and increased variability of Asian summer monsoon precipitation (IPCC, 2001b). Although the issue of food security is directly linked to climate variability and change (Winters et al., 1999; Reilly, 1995), it must be noted that climate is not the single determinant of yield, nor is the physical environment the only decisive factor in shaping food security (Parry et al., 2004).

Despite understanding the multidimensional nature of food insecurity, it remains a key concern affecting the livelihoods of marginal groups. Therefore, understanding the impacts of climate variability, as well as the possible changes in this variability on food security is critical to making improvements in food security. Food insecurity at the household level often results in resources being diverted. For example, resources that might have been used to support the development of livelihoods such as education, health care, and employment, get reallocated to ensure that basic food needs are met. The acquisition of food for marginal groups often entails a delicate balance of producing food for the household under stressed conditions at the same time as drawing on social and economic resources to access available food. When conditions in the environment vary (e.g., climate, soil and water characteristics, and land use changes), this can place an additional stress on food production (McConnell and Moran, 2000).

There are many levels at which a food system can be examined (Stephen and Downing, 2001). Food policy, trade, and resource use are governed by decisions at national, regional, and global levels. Global climate is part of a global system but influenced by the actions of individual large countries such as the United States, China, and India. The boundaries between these systems are not clear. And this is true for the impact of these global, regional, and national systems on the local level of food systems. Yet, it is at the local, individual, and household level that food is used, and it is people who must ensure their access to food; otherwise, they can become food insecure. Although individual access depends on factors at numerous scales, the first level of analysis that determines the nature of food insecurity is the local level of household livelihoods.

In this paper, we examine household food security from a livelihood perspective for a number of regions around the world where food insecurity is a stress to rural livelihoods. We draw on case studies from semiarid regions in Nigeria, Sudan, South Africa, and Mexico and tease out the commonalities and differences from the case studies to learn some lessons about climate variability and food security at a livelihood scale. Although vulnerability to climate change, including vulnerability to food insecurity, is highly differentiated across continents, countries, and livelihood systems, it is important to explore common strands across regions regarding food security and its determinants. Although each of the regions selected for this study is a drought-prone region, they are not all equally vulnerable to droughts. Some, through various policies and adaptation strategies, have reduced their food insecurity resulting from droughts. Sharing their experiences could help other vulnerable regions deal with their food insecurity. Second,, in a globalizing world economy, regional integration is commonly being adopted in solving environmental problems. Identifying regional drought-related food insecurities could also lead to devising regional solutions to tackle such problems.

The four case studies use different research approaches, yet all of the projects focus on food security, climate variability, and climate change. Data for the studies were collected from households using ethnographic and interview research techniques. The household was adopted as the unit of analysis, as the household level tends to be where decisions about household production, investment, and consumption are made in most agrarian societies, particularly under long-lasting drought conditions. Questions that this paper seeks to answer include: What factors determine a household's vulnerability to food insecurity? What are the differences and commonalities with respect to these factors across the study regions? What are the implications of these in addressing climate policy as related to food insecurity at regional or country-wide scales?

2. Climate Variability, Change, and Food Security

Food security depends on availability of food, access to food, and utilization of food (FAO, 2000). Food availability refers to the existence of food stocks for consumption. Household food access is the ability to acquire sufficient quality and quantities of food to meet all household members' nutritional requirements. Access to food is determined by physical and financial resources, as well as by social and political factors. Utilization of food depends on how food is used, whether food has sufficient nutrients, and a balanced diet can be maintained. It is these three facets of the food system that all need to be met in order for food security to be realized. Each of these facets can be impacted by climate variability, and these impacts are discussed below.

2.1 Impact of climate variability and change on food availability

The consensus of scientific opinion is that countries in the temperate, high-, and mid-latitude regions are generally likely to enjoy increased agricultural production, whereas countries in tropical and subtropical regions are likely to suffer agricultural losses as a result of climate change in coming decades (Arnell et al., 2002; Devereux and

Edwards, 2004). It should be noted that the favorable assessment for temperate and high-latitude regions is based primarily on analyses of changes in mean temperature and rainfall; relatively little analysis done to date takes account of changes in variability and extremes. Impact of climate variability on crop production should be a priority given that analyses of agricultural vulnerability indicate that the key attributes of climate change are those related to climatic variability, including the frequency of non-normal conditions (Bryant et al., 2000; Smit et al., 2000).

Climate variability directly affects agricultural production, as agriculture is inherently sensitive to climate conditions and is one of the most vulnerable sectors to the risks and impacts of global climate change (Parry et al., 1999). Many factors impact the type of policies implemented at a national level (such as domestic politics, redistribution of land/wealth, exchange rates, and trade issues, etc.). Climate variability should be factored into these policies, as these policies can impact the availability of staple foods, for example, by providing incentives to grow crops appropriate for the climate conditions.

In the case study sites, the two major forms of agricultural production are arable farming and pastoralism. Because of the limited amount and uneven distribution of rainfall in time and geographic scope at the study sites, rainfall represents the most limiting factor for agricultural and livestock production. Its consequences are well known to local populations: the drying out of water sources, scarcity of grazing land, shortage of dairy products, and loss of wild plants for gathering, migration of grazers, bad harvests, and livestock losses, among others. For instance, it has been estimated by the World Bank that around 10% of the population of Sub-Saharan Africa is primarily dependent on their animals, whereas another 58% depend to varying degrees on their livestock. Increasing population pressures interacting with declining rainfall and reduced pasture has already begun to impact the livestock sector negatively. Rangeland condition is directly affected by the climate (as highlighted in the section on desertification in the i-ntroduction to this volume) and, in turn, directly affects the quality and quantity of small and large stock and associated livelihood activities.

2.2. Impact of climate variability and change on food access

Individuals have sufficient access to food when they have "adequate incomes or other resources to purchase or barter to obtain levels of appropriate foods needed to maintain consumption of an adequate diet/nutrition level" (United States Agency for International Development (USAID), 1992). Food access depends on the ability of households to obtain food from purchases, gathering, current production, or stocks, or through food transfers from relatives, members of the community, the government, or donors. Intrahousehold distribution of these resources is an important determinant of food security for all household members. Food access is also influenced by the aggregate availability of food in the market, market prices, productive inputs, and credit (USAID, 1992). Poor market infrastructure and an unfavorable policy environment may lead to high and variable prices for food and inputs, further undermining agricultural productivity, food supplies, and derived incomes.

Access depends on the physical factors, as well as social and economic factors. After food is produced, it needs to be moved from the point of production to the point of consumption. This often depends on transport systems. In many developing countries, inefficient and ineffective transport systems retard the delivery and increase the price of food. Climate change is expected to place a strain on transport systems (IPCC, 2001a). For example, increased heat stress may reduce the life of roads, and windstorms can impact transit at air and sea port terminals as well as damaging infrastructure which may create delays (Perry and Symons, 1994). During droughts, people are known to move into marginal lands. Most of these marginal lands may not have good road access, and transporting food from such marginal farms poses a huge challenge.

2.3. Impact of climate variability on food utilization

Adequate food utilization is realized when "food is properly used, proper food processing and storage techniques are employed, adequate knowledge of nutrition and child care techniques exists and is applied, and adequate health and sanitation services exist" (USAID, 1992). Food utility involves how food is used. This can include how often meals are eaten and of what they consist. Constraints to food utilization include loss of nutrients during food processing, inadequate sanitation, improper care and storage, and cultural practices that negatively impact consumption of nutritious foods for certain family members.

In many areas where food is produced and consumed locally, food utility changes with seasonal variation and food availability changes throughout the year. The hungry season is the time before the planted crops are ready to be eaten. Similarly, at harvest time, there might be festivals and a lot of food consumed. If there has been a drought and food availability is low, the range of food available often decreases, and so the meal frequency can decrease and the balance of nutrients can be inadequate. This can lead to malnutrition in children. It is also important to note that climate can have an impact on food utility indirectly. For example, if there are hot dry days, crops and vegetables may be dried so that they can be used later in the year. At the same time as seasonal crop production, many households face fluctuations in cash and in-kind income, both within a single year and from year to year. Agricultural households may face seasonal fluctuations in income related to crop cycles. Year-to-year fluctuations in income can result from varying agroclimatic conditions and climate variability.

2.4. Household food security and livelihoods

Livelihoods can be considered as the combined activities and available social and physical assets that contribute to the households' existence (Carney, 1998). Each individual has his or her own means of securing a livelihood, and together, the individuals make up the households' packages of livelihood assets and strategies. These strategies are pursued within a larger context that often determines whether these strategies will succeed or fail.

The livelihoods approach is useful for understanding food insecurity as it emphasizes the importance of looking at an individual's capacity for managing risks, as well as the external threats to livelihood security, such as drought (Chambers, 1989; Scoones, 1998; Carney, 1998; Moser, 1998). It enables the agency of individuals to be captured in their decision-making process (Ziervogel, 2004). For example, if one household has a member who works in the city and remits money and they have a productive field, they spread their access to food sources through their own production and purchasing food. If there is a drought and crops fail, they may still have access to food if money continues to be remitted. If a household absorbs more children through the death of family members, then utilization of the existing food sources may be stressed and the number of meals reduced. This may result in a family being forced to remove children from school so that they can work to try and increase access to food that will result in improved utilization. A government grant may ameliorate this impact. It is clear that food insecurity depends on the agency of individuals and the components of household livelihoods that are interlinked with the three facets of food security, as explained above.

Livelihoods of households can be compared if similar characteristics and activities in household livelihoods are grouped together to cluster livelihood typologies. Examples of typologies might include small-scale farming livelihoods or informal trade-based livelihoods. These help focus on an intermediate system level that draws from the local but has a unit of analysis greater than the local. Recognizing livelihood typologies is a useful construct for comparing livelihood systems between regions (Dixon et al., 2001). A number of livelihood typologies can coexist and can vary in their geographical extent. In some instances, a livelihood typology may draw upon certain environmental resources, such as coastal resources for fishing, and in other instances, they may cross national boundaries, such as livestock-based livelihoods. The predominant livelihood typology for each case study is expanded in detail in the case study section.

3. Case Studies

Case studies examining food security in Nigeria, Sudan, South Africa, and Mexico are compared to identify commonalties and differences in how local food systems are impacted by global environmental change.

3.1. Case Study 1: Mangondi village, Limpopo Province, South Africa

Mangondi village is situated within the Vhembe district, Limpopo Province, in the northeast region of South Africa. Parts of Vhembe district were the former Venda, which was a homeland of apartheid South Africa, allocated to black households, where land was often marginal. Many of the previously disadvantaged farmers in the area have begun increasing the size of their production to try and enter into the fruit and vegetable market. Although there has been an increase in productivity among some previously disadvantaged farmers, there are still many constraints that are faced, and many of the poorer households remain food-insecure and do not have access to production or employment opportunities.

A key constraint to farming in this area is high climate variability, as numerous droughts and floods have occurred in past decades (e.g., 2000 floods, 2002/2003 drought). Managing this climate variability as best as possible is of paramount importance when many other stressors (such as land access, political instability, market fluctuations, globalization, and HIV/AIDS) enter into the equation (Ziervogel and Calder, 2003). Marketing is also a key concern. Although former subsistence farmers have started growing products for sale, particularly when they have access to irrigation, it is challenging to find markets that will buy products consistently, which is due to variable demand, prices, and quality of produce. It is also hard for the producers to ensure quality of supply and quantity, as credit is limited and input and environmental conditions vary.

A communal farming project was initiated in Mangondi village in 1993 that aimed to support women in the production of vegetables for combating malnutrition among children (Archer, 2003). Land was identified and took a few years to prepare and in 1996 it was first cultivated by a group of 59 women and 5 men. Donors initially contributed to setting up the project. A committee that is elected each year now runs the project, with limited donor involvement. In the first year, subsistence crops were planted and in later years, vegetables were planted with the intention of selling. Through the years, the success of the project has fluctuated. In some years, the farmers have had a functional irrigation scheme, money for inputs, and have made profits. In other years, the pump for the irrigation has failed, people have not planted and harvest and marketing has been poor.

Research in this village has been undertaken since 1999 to examine the role of seasonal forecasts and agricultural support among smallholder farmers. Surveys, participatory approaches, and computer-based knowledge elicitation tools have been used to extract the type of adaptive strategies followed under certain conditions and why, with a focus on the role of climate, market, and livelihood needs (Bharwani et al., in press). This is supported by household livelihood profiles, response to the climate, and forecast information over time and access to other information sources.

3.1.1. Food security

This research has focused on participants involved in the communal garden scheme. The available data, therefore, do not represent the entire village. However, extensive work has been done in the area that enables the picture of food security to be painted. The members involved in the scheme have identified an increase in food security since the project started. Participants have stated that they now have vegetables to eat, which they did not have before there was an irrigation project, and as a result, health has improved; vegetables can be sold and the money used to send children to school. When there are surplus vegetables, they dry them so they can be used in months when vegetables are not readily available. The availability of vegetables has also impacted on the quality of livelihoods, as participants now spend less time traveling to nearby markets to obtain vegetables.

The disadvantage has been that the irrigation project relies on a pump that is often broken primarily because it is too small for the garden (Archer 2003). This has meant that time and resources have been invested in the garden, and when the pump is broken, these resources are wasted. It is also uncertain as to when the pump will be fixed, which makes it hard to plan and hard to market crops. The limitations of the pump can therefore make people more vulnerable when they are expecting and investing in a harvest that does not materialize.

The food security of members not involved in the project depends on individual situations. The land is relatively fertile and there are numerous fruit trees. Many households have some livestock (such as cattle) or smallstock (such as chickens). The field crops can provide food when rains are good, but it is not uncommon for whole crops to fail when the rain is insufficient and irregular. Farmers who produce surplus are able to sell some of their vegetables, but marketing is a key constraint, and there are not big consistent markets. There are many households in the area in which members are sick, and households are struggling to survive, as they do not have access to labor for production or to alternative employment. In South Africa, there is a grant system that supports many households and enables them to buy food. Grants are available in the form of pensions, child grants (for each child up to 8 years old, if household income is below a certain amount) and disability grants. Disability grants are available for the physically disabled, which includes people who are unable to work because of AIDS. The increased occurrence of HIV/AIDS has an impact on food security, as increased amounts of food and appropriate nutrition are needed, while labor decreases, and resources are spent on health rather than agricultural production.

3.2. Case Study 2: Gireigikh rural council of Bara Province of North Kordofan State, Sudan (Sudan AIACC Project, 2003)

The Gireigikh area lies in drought-prone Western Sudan, North Kordofan state, typified by the semi-arid and desert scrub of the African Sahel region. The area is characterized by harsh climatic conditions and erratic seasonal rainfall. The predominant socioeconomic grouping consists of a mix of agro-pastoralists and transhumants who are extremely vulnerable to drought. The key ongoing pressures are the degraded rangelands, and strong sand dust storms in the region. The current vulnerabilities result from changes in climate variability, particularly aggravated by the long-term and intense droughts. Dry conditions, such as the current Sahel drought, are not uncommon in Africa. Hoelzmann et al. (1998) found that much of what is desert in Africa today was covered in steppe vegetation, and that many small lakes and streams existed above 23° North latitude where they currently do not exist. This desertification is combined with problems of soil erosion and failing livestock and crop production. These factors directly affect food security problems, which lead to loss of rural livelihoods and displacement of the rural people.

3.2.1. Food security

The Community-Based Rangeland Rehabilitation Project was implemented in Bara Province of North Kordofan state, a semiarid land that receives a long-term average rainfall of 275 mm annually (Dougherty et al., 2001). This amount was sufficient to maintain people's livelihood and establish their staple food crops, which are mainly millet and sorghum, in addition to raising animals. However, the area has been affected three times by drought episodes between 1976 and 1992, with the most severe drought occurring in 1984. The drought of 1980–1984 highlighted the basic problems that have been ignored for too long; family and tribal structures and their autonomous traditional practices of resource management and land tenure had broken down (Dougherty et al., 2001). Two tribes inhabit the study area: the Gawama'a and the Kawahla. The Kawahla are a nomadic tribe that settled in Gireigikh after they lost their herds due to a drought that hit their previous areas of settlement in Eastern Kordofan during the period 1967–1973. The Gawama'a were originally farmers and herders of cattle, sheep, camels, and goats. After continuous drought cycles hit the area, the Gawama'a lost all their cattle and most of their sheep, camels, and goats and were forced to shift from keeping livestock to farming crops.

The Gireigikh area is semiarid with sandy soils of low fertility. The area is highly vulnerable to wind and water erosion and is not suitable for the continuous agricultural cropping now being practiced, which has exhausted the soil and led to severe land degradation. To compensate for this, and in the absence of inputs, (such as fertilizers and improved seeds), Gawama'a expanded the growing area in order to produce more quantities and sell part of it to raise income for other household expenses. Despite the agricultural extensification, the situation did not improve. The majority of the interviewed farmers indicated that what they have previously used to get out from an area of 5 hectares (crops and livestock) was more than what they were getting from a 50-hectare area after the 1980s drought. Vast tracts of land were turned completely barren with no trees and all the below-canopy herbaceous species removed. The amount that was produced was not enough to sustain their food requirement for the whole year, and they often ended up with severe food shortages.

To make up for the meager income made from this kind of agricultural practice, young men had to travel, leaving the women behind, to seek for jobs in nearby towns or in the capital city of Khartoum. Some also worked as seasonal laborers in irrigated schemes all over the country, with the majority working in fruit and vegetable gardens along the Nile in the Northern State. Again, what was earned by most of them from these seasonal jobs was not enough to cover their families' immediate needs, such as paying for school fees, health services, or other needs. No savings could be made from such little wages and, consequently, low affordability to buy food from other markets outside the state. Most suffered from many environmental and nutrition/health-related problems. The prevalence of malnutrition diseases was high among women, especially the pregnant women and also among children, as indicated by 70% of the respondents; moreover, only 34% of the total population has access to health services (Sudan AIACC Project, 2003).

With the droughts, water quantity became a limiting factor for the people to practice any alternative livelihood activities e.g., growing vegetables, fruits, or raising poultry. Women were known to walk long distances to fetch meager quantities of water from a hand-dug well, which was both time and health consuming. To address these problems, a project titled "Community-Based Rangeland Rehabilitation for Carbon Sequestration and Biodiversity Conservation in North Kordofan State" was initiated by the United Nations Development Programme (UNDP) Global Environment Facility (GEF) during the period (1994–2000). The project objectives were *1*) to sequester carbon through the implementation of a sustainable, local-level natural resources management system that prevents degradation, rehabilitates, or improves rangelands; and *2*) to reduce the risks of production failure in the drought-prone area by providing alternatives for sustainable production, increasing the number of livelihood alternatives so that out-migration would decrease and population would stabilize.

The stakeholders involved included the community of Gireigikh Rural Council, the Range and Pasture Administration office of North Kordofan State, and the Federal Range and Pasture Administration. They implemented awareness and institutional building to mobilize and organize community groups for project planning and implementation. They also provided training in a wide range of activities to build local capacity for project implementation and ensure project sustainability. Rangeland rehabilitation activities carried out include land management by means of range conservation and rehabilitation, assigning grazing allotments to herders on rotational basis to restore soil productivity, livestock improvement (replacing goats, which are aggressive browsers and grazers, by the less aggressive sheep), and the introduction of agroforestry systems and shelterbelts for improving soil fertility and provide for sand dune fixation. Additional community development activities were implemented to address immediate needs such as water harvesting and management, rural energy management, and diversification of local production systems and income-generating opportunities, thereby reducing pressure on rangeland resources.

The project adopted an institution-building approach where Implementation Committees and Coordination Committees were created in village communities. Several training events were held to enhance community development and improve natural resource management, pest management, diversification of income, and cottage industries. Although the participation from the community was voluntary, the involvement of women in all these activities was largely encouraged.

The reported outcomes from the Bara Case study Report (Sudan AIACC Project, 2003) include the establishment of local institutions, such as the Village Community Development Committees, to coordinate community natural resource management and community development activities; development of land-use master plans to guide future resource use and implementation of sustainable rotational grazing systems and establishment of community mobilization teams to conduct outreach and training; reforestation and stabilization of 5 km of sand dunes to halt desert encroachment and soil erosion; restocking of livestock by replacing goat herds with more resilient and less resource-damaging sheep; creation of a water management subcommittee to better manage wells; the establishment of 17 women's gardens to produce vegetables for household consumption, with surplus sold at local markets; the establishment of five pastoral women's groups to support supplemental income-generating activities, including sheep fattening, handicrafts, milk marketing, planting of shelterbelts (195 km) around

130 farms to act as windbreaks and to improve soil moisture and increase fertility (Dougherty et al., 2001).

There have been a number of positive outcomes for the ecosystem from the project. The impact of the project on the natural and financial capital, have contributed more to the success of the project in achieving one of its major objectives as shown in Figures 1 and 2. Figure 1 was generated from househhold responses to questions revolving around indicators used for assessing the sustainability of the interventions addressing financial capital, as described in qualitative terms and translated into score values.

Figure 1 shows the profound change from poor financial conditions that used to prevail before the project to a big change after the intervention (up to 80% from less than 10%). Information on indicators such as "effectiveness of credit repayment revealed that, the money of the revolving fund was primarily used for buying animals for fattening and marketing them in big state markets, hence fetching higher prices. Moreover, it offers necessary funds for the Natural Resources Committee to support other activities such as seed distribution for women's irrigated gardens and the purchase of improved stoves. This led to the conclusion that the improvement of financial capital could contribute to the improvement of other livelihood capitals, such as the natural, human, as well as the physical capitals. Moreover, the presence of reliable local level institutional structures (e.g., the Sudanese Environment Conservation Society (SECS) Bara Branch along with the Community Credit Committees and Coordination Committee) provided a guarantee to the local community that enabled their access to credits.

Figure 2 was generated from household responses to questions revolving around indicators used for assessing the sustainability of the intervention addressing natural capital, described in qualitative terms and translated into score values. The intervention consisted of a package of activities, including rehabilitation and sustainable management of the rangelands using grazing allotments, in which the range area was divided into compartments, to be grazed on a rotational basis, where grazing is confined to one compartment at a time, then shifted to the second leaving the grazed one to regenerate and restore its fertility and so on. The indicators used encompassed the rangeland quality, adoption of grazing allotment system, and shifting from agriculture to range and the quality of animals. The results were the enrichment of the rangeland and the reappearance of highly preferable pasture species that had long vanished from the area. Other improvements included mud-wall building instead of wooden huts, improved stoves (utilizing less charcoal), and sheep-fattening (in place of goats). The study showed that these ideas were widely adopted by the community, and their values were highly appreciated as reflected in the responses by more than 70% of the respondents. Mud-walled buildings and improved stoves considerably reduced the rate of depletion of the forestry and other vegetation cover. The mud-walled building was highly favored not only in the project area but also in nearby villages (outside the project area).

In order to assess the impacts of the project, an AIACC research project was undertaken. The project employed the Sustainable Livelihood Framework to assess adaptation strategies to climate change. The notion of the five capitals (natural, physical, human, social and financial) was used to evaluate the impacts of the project intervention over each of the capitals as perceived by the communities. Consequently, the data capture process captured the perceptions of the local community toward the coping/adaptive capacity using a combination of qualitative and quantitative indicators.

The project team developed lists of generic[7] quantitative and qualitative indicators around the five capital assets in the sustainable livelihoods framework, that is, those that are relevant to rural, drought-prone settings in Sudan. The team also tried to generate indicators that represent a balance between productivity, equity, and sustainability across the five capitals. Generic indicators related to livelihood identified include:

- Land degradation (slowed or reversed);
- Condition of the vegetation cover (stabilized or improved);
- Soil and/or crop productivity (stabilized or increased);
- Water supply (stabilized or increased);
- Average income levels (stabilized or increased);
- Food stores (stabilized or increased);
- Migration (slowed, stabilized, or reversed);

In order to assess the impacts of project measures on the community's livelihood, a survey was conducted, for which 31 interviews were conducted over a period of two weeks covering 0.5% of a total target of 6,116 people (approximately 1,018 households). Almost all of the respondents in the study indicated their being highly vulnerable during drought periods and acknowledged that the project intervention did increase their resilience across the five capitals through its introduction and support of different activities. The different assets of the five capitals were found to work in harmony in a very well integrated manner. The presence of diverse activities was one of the most important things for increasing the resilience of the community. The best situation was found in the natural capital, which showed strong positive indicators regarding the recovery of local fauna and flora, reduction of sand dune formation, improved productivity and rangeland carrying capacity, something that presumably stands for the success of the project in achieving one of its major objectives. There were also good indicators for the change of thinking in the community under study. A good example was the modernization of the traditional women's garden (the Jubraka or backyard farm) into the modern women-irrigated garden. These combined interventions enabled the local communities to stand against the major cause of their vulnerability, drought, and brought about a general increase in their adaptive capacity toward harsh climatic conditions that could act as a baseline foundation for building future climate change adaptation strategies.

3.3. Case Study 3: Chingowa village, Magumeri Local Government Area, Borno State of Nigeria

[7] Represent a set of sustainability indicators that is developed as expert-derived ones to be revised and adapted by local communities.

Chingowa village is located in Magumeri Local Government Area of Borno State in the Sahel zone of northeastern Nigeria. It has a mean annual rainfall of 600 mm, which falls in the four months of the rainy season, which lasts between June and September. Agriculture, which is rain-fed, is primarily supported during the short rainy season, except around the oasis that supports perennial vegetable farming. The vegetation consists mainly of shrub grassland, which is favourable for extensive grazing.

Drought has been a recurrent feature in the Sahel, with early records dating back to the 1680s. The magnitude and intensity of these droughts have been on the increase over the last 100 years, and, consequently, in the destruction caused by it (Hulme, 2001). The most prominent of these droughts was that of the early 1970s, during which hundreds of thousands of people and millions of animals died (Mortimore, 1998). The Palmer Drought Severity Index shows that the Sahel is still experiencing drought conditions. With global warming, Africa will "... experience marked reductions in yields, decreases in production, and increases in the risk of hunger as a result of climate change" (Parry et al., 1999). It is possible then to expect that the region, including Chingowa village, might experience a deficit of precipitation, considering the HadCM3 experiments (Hulme, 2001). Most of the climate change scenarios follow this projected pattern (Ruosteenoja et al., 2003), particularly during the months of December to May. From May to November, some models project increases above 50% (or even above 200%) from the normal values. This could increase the exposure to drought of the already vulnerable population in the village that has witnessed all of the droughts that have occurred in the Sahel, with the last one as recent as 1984, which threatened the livelihood systems in the village. Because irrigation is either not practiced at all or in primitive form, most farmers are unusually vulnerable to economic impacts of climatic fluctuations. These problems may become more severe if changes in the global climate occur as projected climate models (IPCC, 2001b), affecting livelihood systems and consequently food security (Jagtap and Chan, 2000).

The lack of water, in association with high temperatures (up to 45°C at certain periods of the year), is the most limiting factor for agricultural productivity in the village. Millet, sorghum, cowpeas and maize are the dominant food crops grown in the village. Farmers are predominantly smallholders using traditional farming systems. which mix food crops and cash crops on the same farming unit. Because crop farming is largely rain-fed in the village, this will be accompanied by a shift in the traditional areas of production of certain crops, with all the possible negative consequences that this may bring to the local people. The rearing of livestock is a very important aspect of life in the village, as it represents livelihood, income, and employment. Recurrent droughts have forced some pastoralists to dispose of their cattle, lose their livelihood systems, and ultimately increase their vulnerability. The southward movement of the isohyets has also resulted in the southward migration of pastoralists into lands formerly occupied by sedentary farmers. This has been a major source of conflicts in the village leading to widespread destruction of farmlands and cattle, with adverse implications for food security.

This paper is part of a larger project that aimed at examining the vulnerability of rural households in the West African Sahel to droughts. In this paper, we adopt the IPCC definition of vulnerability as the extent to which a natural or social system is susceptible to sustaining damage from climate change, and is a function of the magnitude of climate change, the sensitivity of the system to changes in climate and the ability to adapt the system to changes in climate. Hence, a highly vulnerable system is one that is highly sensitive to modest changes in climate and one for which the ability to adapt is severely constrained (IPCC, 2000a).

To achieve the objectives of the project, we adopted a framework that combines the vulnerability/risk framework (after Downing et al., 2001) and the Vulnerability Assessment Framework (after Jones, 2001). It focuses on *current* vulnerability, *risk* of present and future climatic variations, and *responses* to reduce present vulnerability and improve resiliency to future risks. It places the stakeholder at the center of the research. This is very important in our project, as the people in the region have developed indigenous knowledge systems that have enabled them cope so far with the drought phenomenon. In addition, other stakeholders have various levels of experience in developing and implementing projects of this nature in the Sahel. Our methodology included data collection through the administration of questionnaires, focused group discussions, stakeholder analyses, and field sampling. This case study looks at vulnerability to food insecurity in Chingowa village in Borno State of Nigeria, where questionnaires were administered to 30 farm households in the village. The research has shown that one of the highest concerns among the respondents is the fear of famine, and consequently, the problem of food insecurity.

3.3.1. Food security

In assessing food insecurity in the village, we examined various factors that predispose households to being vulnerable. These factors include agricultural productivity and production, labor availability and land tenure, food storage and processing, transportation and distribution, population factors, income, and conflicts.

The size of land that a household cultivates directly affects their production and hence food security. Population growth has led to a high level of fragmentation of land in the village. Hence, acquiring a relatively large tract or tracts of land for farming is a difficult task. A majority of the farmers in the village are smallholders who cultivate less than 5 hectares of land (61.2%). Only about 19% of the respondents used irrigation, with just less than a third of them irrigating more than half of their total farm lands.

The existing tenurial arrangements in the village also affect agricultural production in the village and pose a constraint to sustainable food security. There are socio-cultural factors that prevent women from having title to land in many parts of the country, including Chingowa village. Various studies have shown that women produce between 60 and 80 percent of the food in most developing countries, including Nigeria. Although women are the mainstay of small-scale agriculture, the farm labor force and day-to-day family subsistence, they have more difficulties than men in gaining access to resources such as land, credit, and productivity-enhancing inputs and services. In Chingowa, ownership of farmland is predominantly acquired through paternal inheritance, which, to a large extent, excludes the women. However, some respondents cultivate lands that are communally owned, purchased outright with private ownership, rented, or borrowed. A higher proportion of the respondents (43%) cultivated communally owned land, while 37% of the respondents cultivated lands they personally owned through outright purchase. Twenty percent of the respondents cultivated rented lands, while about 17% cultivated borrowed lands.

The main crops cultivated in the village include maize, millet, sorghum, and beans. Self-reported harvests show that a household harvested an average of 48 bags of cereal per year. Other factors that affect agricultural productivity in the village include the unavailability of inputs, particularly fertilizer and improved seeds, and poor transportation infrastructure, which has adversely affected market access. Chingowa village is situated at about 1.5 km from a good motorable road and 6 km from a daily market. Net farm income is very low, and average annual household income from all sources is N63,000.00 (1 USD = 134 Naira). With low agricultural productivity in the village, the population has had to continue to rely on other sources of income in order to meet household demand for food and other needs. In addition to arable farming, pastoralism is a major economic activity in the village. The most common domesticated animals in the village are cattle, poultry, goats, and sheep. Cattle are generally kept at the commercial level, while the smaller animals: goats, sheep, and poultry are kept at the subsistence level. When expressed in TLU, or tropical livestock units, cattle are the most important type of animal among households, followed by goats, poultry, and sheep. The poultry include chicken, duck, turkey, and guinea fowl. Virtually every household keeps poultry and some goats and sheep.

It is expected that households that are self-sufficient in food are less vulnerable to food insecurity than those that are not self-sufficient. Forty-eight percent of the respondents in the village do not produce enough grains to last them till the next harvest. Of this proportion, 51% say their harvested grains last them for up to three months, for 28% of the respondents, the grains last between 3 and 6 months. Only about 21% of the respondents harvest enough grains to last them more than 6 months.

Labor is a critical input in the traditional, subsistence farming system practiced in the village. The farmers plant very small areas at a time, using crude implements and labor-intensive practices. As a result, the demand for labor is generally very high at the time of planting, weeding, and harvesting. Two main factors that affect the availability of labor in the household are rural-urban migration, and the quality of the household. With rural-urban migration, able-bodied young men of productive age migrate to the urban centers in search of nonfarm employment. Once the young adults in the family leave, many farm families are left with only aging parents and possibly the very young children. This phenomenon increases the dependency ratio in the household. The quality of a household is conceptualized as the ratio of healthy working members of the household over the sick members, as captured in the dependency ratio. With the spread of killer diseases such as malaria, HIV/AIDS, cerebrospinal meningitis, the quality of available household labor is seriously compromised.

The problem of inadequate storage facilities has compounded the problem of food security in the village. It is estimated that about 15–20% of cereals and up to 40% of perishable crops produced are lost before they can be consumed. This situation is made worse by the dearth of any agro-processing industry close to the village. It also has a discouraging effect on the farmers as the struggle to sell most of their crops immediately after harvest results in a very unprofitable competition and lower prices.

The village has witnessed several communal crises, largely between the pastoralists and the sedentary farmers. These conflicts have largely arisen through the struggle for resources, which have been exacerbated by the frequent droughts and the downward shifts of the isohyets. These conflicts are a major constraint to food security in the village. The crises usually occur either during planting, weeding, or harvesting period and with the flight of farmers from the areas, irrespective of the stage of farming, food security is threatened as most, if not all the crops are lost. The pastoralists also suffer significant casualties in the loss of livestock.

3.4. Case Study 4: Rain-fed Maize Production in Tlaxcala, Mexico

Rain-fed maize production is the most important agricultural activity for the majority of subsistence farmers in Mexico. It is traditionally cultivated in a surface called *milpa*, which includes other cultivars (such as beans and chile) and plants used for medical and food preparation purposes. Maize has been planted in the country for thousands of years, and it constitutes the basic food in the Mexican nutritional regime. This activity is strongly affected by climate variability, particularly drought events that have forced farmers to apply different strategies to cope with it (Florescano, 1995). In Mexican history, hunger and famine have been present and related to severe drought events, in which great losses in maize production have affected both rural and urban populations. The impacts of these events have been exacerbated during the most important civil wars in the country (Independence, Mexican Revolution).

Nowadays, farmers who rely on rain-fed crops, apply different strategies to cope with drought, including switching to more pest-resistant maize varieties, changing cultivars, seeking temporary jobs in urban areas, renting their fields, or even emigrating to the capital city of the state, cities in other states, or to the United States of America.

In 2004, 10.23 million Mexican migrants lived in the United States, a population that has grown at an annual rate of 4.2% since 1994 (CONAPO, 2004). In the same year, 16.6 million US dollars were sent by migrants to Mexico (BancodeMexico, 2004). This flux of income has represented a basic support to preserve or enhance the levels of nutrition, health, and education of the rural population, particularly for the rural villages with less than 2,500 inhabitants (Lozano, 2005).

This situation was mainly forced by the aggressive changes in the governmental policies related to economic liberalization of agriculture, particularly since the North American Free Trade Agreement (NAFTA) came into effect in 1994 (Nadal, 2000).

In the last decade, basic grain importations have increased by almost 40%, and maize importations have doubled, even though in NAFTA, it was established that the total liberation of maize (and beans) importations will occur by 2008 (Bartra 2003). In general, the structural reforms in the agricultural sector have implied the removal of subsidies for seeds, agrochemicals, energy and water; the reduction of credits, and the elimination of the governmental control of prices. All of these measures have caused an increase in production costs and a reduction of profits for maize producers.

Mexico has thus become one of the major importers of food: 13 503 000 000 USD was spent on importing food in 2004. (BancodeMexico, 2004), and Mexico now occupies the third place in world maize importations, just below Japan and Korea.

The high genetic diversity of maize in Mexico (forty-one racial complexes and thousands of corn varieties; Nadal, 2000) is also threatened by the massive importation of corn, reducing the availability of Mexican varieties that could be adapted in the future to new climatic conditions. In addition, out-migration of farmers also erodes traditional knowledge associated with those varieties (called *criollas,* as opposed to hybrids).

However, farmers in Mexico are still focusing their efforts on producing maize, pointing out the importance of this production to households' food security. As a result of adverse factors, farmers are expanding the area of maize cultivation, even to areas where soils and climate are unfavorable, and increasing the pressure on forests and other ecosystems. Even though yields have declined, Mexican production of corn has been stable since 1988, except for 1998, when corn production was affected by a severe drought (Nadal, 2000), caused by the strongest El Niño event in the last 20 years. This is in contrast with the abrupt decrease of 45% in the relative price of maize and the accelerated increase of the price of tortilla of almost 279%, for the same period of time (mainly because of the elimination of all subsidies to the production and consumption of tortillas).

Maize is the basic element in the Mexican diet. In 2004, 112 grams per person were consumed, which contributed 50% of the total daily calories and 71% of the daily proteins Mexicans consume, particularly in the form of tortillas; each Mexican consumes 104 kg per year of tortillas (Rosas-Peña, 2005). The data collected in 2002 by the governmental agency, the National Institute of Statistics, Geography and Informatics (INEGI), showed that the poorest households (first decil; Group I) in Mexico spend more than 40% of their income dedicated for food on tortillas, while the richest households (last decil, Group X) invested less than 10% (Figure 3).

With the lack of markets for their products, farmers have experienced an increase in poverty. Meanwhile, the cost of the basic tortilla has increased for urban and rural populations, threatening the food security of the poorest people in the country.

Maize production for subsistence has been an activity pursued by rural families, particularly by the indigenous communities. Given the increasing lack of young men in the Mexican fields, subsistence agriculture has become an activity where women, children, and old men are struggling to produce maize as the basic element of survival in their region. Family incomes have also diversified, receiving important support from migrants, but also an increase in temporary jobs of women, renting lands and diverse governmental support, particularly when climatic events adversely affect agricultural productivity.

In 2004, the Minister of Agriculture contacted the Center of Atmospheric Sciences to evaluate a program that supported farmers when "climatological contingencies" affected production during 2003 (Gay (PI), 2004). During that year, 200,500 farmers received economic support from that program (Cortés, 2004), and a survey was applied to a representative sample in five states of the country. The most relevant "contingency" identified by farmers was drought (Cortés, 2004), an event that is still the main source of agricultural loss in Mexico, as can be seen in Figure 4, where more than 80% of the planted areas in the country were affected by that extreme event during 2000 and 2001, and more than 60% of the total planted area were also damaged by drought during 2002 and 2003. The most affected crop in the country during 2003 was maize, which was mostly used by farmers for household consumption. The average age of the farmers was more that 50 years, and one-third of them were women (Cortés, 2004).

A specific case study that can illustrate what is stated above is the case of maize production in Tlaxcala, Mexico. Climate change and climate variability studies have been carried out in this state since 1997 (Ferrer, 1999; Conde and Eakin, 2003).

The state of Tlaxcala is located at the center of the country, in the Mexican high plateau. It is the smallest state in the country, where 98% of agriculture is developed under rain-fed conditions (INEGI, 1996), with only one harvest a year (Trautmann 1991), with maize being the most important crop (71% of the total planted surface).

During spring, farmers in Tlaxcala wait for the onset of the rainy season by April, and with a delay in this event they start considering changing varieties of maize or even changing to another crop. This situation could be clearly observed during the strong 1997 –1998 El Niño event, when oats (forage) were planted known as the "hopeless crop," as a desperate measure, just to prevent cattle losses, while the expectation of planting maize was abandoned (Aviles, 2005). A few years later, farmers returned to plant maize (Conde and Eakin, 2003), because alternative crops are planted only during extreme climatic events, but not as a rule to adapt to adverse market conditions.

Further studies (Conde and Ferrer, 2003) have shown that farmers perceived changes in climatological conditions, to a situation where more extreme events have prevailed and where drought is the most worrisome event for the agricultural activities. Since maize prices have significantly decreased, the cost of fertilizers and other inputs have increased, and there is a lack of labor force from younger farmers, a drought event severely affects their capacity to cope with the possible changes in climate. Also, agricultural policies and supports are more centered toward the production of fruits and vegetables for exportation, not taking into account the high consumption of water of those products in a context of climate variability and change, associated with past and future droughts in the country.

Other environmental factors raise the risk of increasing losses in maize production. Tlaxcala is the state with the worst soil erosion conditions (SEMARNAT 1996). Even when farmers are aware of soil conservation techniques (Conde and Eakin, 2003), they cannot practice them, because those require strong collective work, and families are being reduced in number because of migration or changed labor, so they are forced to develop maize monoculture production in extended areas, which reduces soil productivity and increases the soil erosion processes. Also, the reduction of crop diversity (Altieri and Trujillo, 1987) increases climatic risks and reduces the farmers nutritional opportunities.

3.4.1. Food security

The agricultural policies developed over the last 20 years in Mexico related to food security have shifted from a view of self-sufficiency agricultural production to a policy that seeks to secure access to food resources, following the globalization of economic processes. Government support for the rural population now focuses on programs that deliver economic help for those needing to acquire basic goods (i.e., tortillas or milk) at reduced prices, but not as a policy to sustain the traditional maize production (*milpas*). The current government has declared that subsistence farmers have five years to be "efficient and competitive" in the international markets, or to "look for another activity" (Bartra, 2003). Even though in NAFTA, it is established that until 2008 the Mexican market will be totally open to corn importations, and maize and tortilla prices have been adjusted to the requirements of international markets resulting in a decrease in national maize prices and an increase in tortilla prices.

Before 1998, the tortilla prices were subsidized by the government, in a policy that focused on guaranteeing food security for the increasing urban population (Appendini, 2001). The costs of its production were mainly transferred to consumers, but the benefits of the increase in prices of tortilla did not reach the maize producers. The massive importation of corn from the United States at lower prices than maize produce in the country (Bartra, 2003) reduced the possible profits for Mexican maize producers. Traditional production of tortillas has also been mostly abandoned, and the corn flour production has been controlled since the 1990s by huge companies such as Grupo Maseca (Rosas-Peña, 2005). Those companies are free to import forage corn from the United States and use it for processing tortillas for Mexico City, for example.

Food insecurity for maize farmers in Mexico, particularly in Tlaxcala, is therefore increasing, considering the described policies and other factors such as the decrease in human resources (migration and farmers' aging), and in the environmental resources. The financial support given by the governmental programs to maize farmers that have suffered the impacts of climatological contingencies, which are delivered late and in reduced amounts (Cortés, 2004), does not solve the decreasing productivity and the lack of a market for their products.

These governmental and macroeconomic policies and trends tend to reduce farmers' ability to manage with adverse climatic events. In this context, new threats, as transgenic maize or climate change, will be difficult to cope with. However, rain-fed farmers continue to plant maize as a means to subsist, making total corn production in the country more or less stable, but increasing planting areas and impacting soil and forest ecosystems.

Several authors considered that a national food security policy should be linked to environmental sustainability and social equity (Appendini, 2001), particularly related to the social right of rural communities to work (Bartra, 2003) and of consumers to chose the quality of the tortillas they eat.

4. Analysis and Discussion

These four case studies exhibit a number of similar trends as well as demonstrate distinct differences. In the South African case, it is evident that there is a clear tension between natural environmental stress of precipitation variability and the social system that determines the welfare options and employment options available. If access to money through employment or grants is available, then food can be acquired through exchange, but those depending on household production are directly exposed to climatic variability, as well as market fluctuations. It is important to recognize that those households relying on grants or income might still be impacted through secondary-order sensitivities, where jobs may decline due to climate variability, such as decreased employment on commercial farms when harvests have failed. Research has shown that the poorer households tend to respond to climate variability in multiple, low-input strategies, whereas the better-off households focus on a few strategies often with higher risk (Bharwani et al., in press). Fieldwork has supported the fact that that food security interventions need to be sensitive to user characteristics and strategies at the same time as supporting institutional developments that enable vulnerable households to cope with loss of livelihood options through a range of stresses, including climate variability, unemployment, or ill health.

Although drought is often regarded as the major cause of food insecurity in semiarid northern Nigeria, the study found that household factors contributed more to food insecurity than climate factors. These household factors include the size of land available to the household for cultivation and the labor available in the household to cultivate the land. The farmers are largely subsistence farmers using crude farming implements with little farm inputs such as fertilizers, irrigation, insecticides, pesticides and improved crop varieties. Where crop production is largely dependent on the size of a household's land holding, a common strategy for increasing production is largely through land extensification. This usually results in the cultivation of marginal lands that have hitherto been occupied by pastoralists. This encroachment often results in conflicts and destruction of cattle and crops, further reinforcing food insecurity in the region. Belonging to a community organization was another major factor in food security in the region. There is no organized welfare system in Nigeria, and these local community organizations provide safety nets to their members in times of crises. The study estimated that about 15–20% of cereals and up to 40% of perishable crops produced are lost before they can be consumed. Food storage was an important issue in food security. Minimizing this level of waste would make more food available for consumption.

Food insecurity in northern Nigeria is also a "food access problem." This is could be linked to poor governance, where infrastructure such as roads are concentrated in the urban centers with very little being provided in the rural areas. This makes it difficult for farmers to transport their goods from the farms to the markets. Besides the general lack of roads and transportation services, the high cost of fuel adds to the cost of transportation, which makes the final prices of the goods very expensive and beyond the reach of the majority of the rural poor. It could also be linked to poverty and the inability of poor people to access food and other resources. Over the longer term, poverty contributes further to food insecurity as it restrains households' potential for accumulation and growth. In view of this, it is important that government seek to provide physical infrastructure in the rural areas, as well as provide seasonal input credit and long-term financing of farm investments. In Sudan and Mexico, it was also clear that climate variability alone does not determine vulnerability to climate change. Rather, it is the livelihood characteristics overlain with social and economic environments and climate variability that determine the vulnerability of households to food insecurity and climate change.

In order to assess the similarities across the cases more systematically, the key vulnerabilities in each case study have been compared by assessing the role of determinants in five groups: climate, environmental, food economy, household factors, and social and human environment. The determinants were scored on a scale ranging from 0 to 2 (where 0 indicates that the factor does not appear to be a key determinant of vulnerability, 1 suggests it is an important determinant and 2 that it is very important). These scores were derived from expert judgment of the authors, based on their interpretation of stakeholder perspectives. This method has its limitations, as it does not have stakeholder feedback but provides an initial analysis of where similarities and differences between the cases lie. It is important to note that this comparison is based on the four case study sites: in South Africa, Mangondi village, in Sudan, Gireigikh rural council, in Nigeria, Chingowa village, and in Mexico, Tlaxcala, rather than on the countries as a whole.

A summary of the key determinants is presented in Table 1. It is clear from the comparison that there are many common factors that influence household food security. The most important determinants of household vulnerability to food insecurity across all four case studies are trends in precipitation, input price, household income, income diversification, belonging to local community institutions and disintegration of social fabric. The next most important determinants include the occurrence of recent droughts, the size of land cultivated, the labor per hectare of farm land, poor health services, and participation in off-farm employment. It is clear that there is a mix of physical, social, and economic factors that determine vulnerability to food insecurity in all of the case studies.

Given that the common vulnerabilities have been established, an objective way of comparing the strengths of the determinants across the various study sites is needed. The key determinants for five categories (climate, environmental, food economy, household factors, and social and human environment) as mentioned above, were ranked as to their role in determining vulnerability in each case study. The mean score for each group of determinants is plotted on a radar graph for each case study (Figure 5). This illustrates that climate factors played a similar role in determining vulnerability to food insecurity in Mangondi village, South Africa; Gireigikh rural council, Sudan; and Chingowa village, Nigeria. Climate did not appear to be a major factor in Tlaxcala, Mexico. Generally, household factors played a more dominant role among all four countries and appeared to have the largest influence on vulnerability to food insecurity. This is a significant finding that should be explored further.

Another way to compare the relative importance of the factors affecting food security is to place each factor in a conceptual framework. For the purposes of this synthesis, we choose a straightforward set of factors that link the underlying use of resources, exposure to drought, and the consequences of food shortage (Figure 6). The focus on drought is justified, as this is the major climatic factor affecting food security in these four case study areas. Of course, drought is not a sufficient cause of food insecurity, and the framework attempts to place drought in context.

The upstream context begins with the identification of human needs (nutrition) and wants (the choice of diet to fulfill nutritional needs), along with the choice of cropping systems (or food procurement systems, more generally) to fulfill the dietary preferences. The hazard-sensitivity elements include the initiating events (drought, or a combination of drought and other factors), the first-order impacts (such as crop failure), leading to initial outcomes, including household food scarcity. Differential vulnerability is apparent in the range of exposures to the first-order impacts and their sensitivity to the consequences (from increased disease burden to death, plus environmental, social, economic, and political consequences). At each stage, a range of actions can intervene to disrupt the causal chain (that is, to prevent further impacts and consequences) or to shift the chain of events to other pathways (for instance, to shift household food scarcity to regional markets, leading to increased food prices and imports to the region).

This framework is used to map the determinants from the case studies against the causal chain as shown in Table 2. The most striking similarity, based on the interpretations of the expert teams, is in the initiating events—the importance of trends in decreasing precipitation, generally accompanied by drought. Health status and health services are seen as the major factors influencing the outcomes of a climatic stress. The range of factors under the categories of structural vulnerability and impact sensitivity are similar, but often with different degrees of importance. For example, off-farm employment is a major factor for the wealthier two countries, South Africa and Mexico.

These two countries show subsidies, pensions, and welfare systems as the most important structural factors, which are not as prominent in Sudan and Nigeria. This could be due to the fact that there is a healthier economy and therefore more job opportunities.

5. Conclusion

Vulnerability to food insecurity is common across the world in semiarid areas where marginal groups rely on rain-fed agriculture. This paper has started to compare some of the dynamics associated with these commonalities. This is particularly important because it is well established that food insecurity is not solely about climate, but about a range of social, economic, and political factors that are linked to physical factors. At the same time, the shift in climate patterns associated with climate change requires an understanding of how climate variability has an impact on food security in conjunction with other determinants.

The causal chain of drought risk helps to highlight the process of becoming vulnerable to drought. In most of the case studies, the determinants of vulnerability are spread throughout the continuum, indicating that there are multiple ways to modify and change the risks. This highlights the need to understand the problem so that interventions can be appropriate in nature and timing.

If one looks at the four case studies, it can be seen that household factors played a dominant role in determining vulnerability. Although this is not unexpected, it suggests that there needs to be a continued emphasis on the multidimensional integrated approach to assessing vulnerability to climate variability. This needs to be followed through when responding to climate variability, whether through climate adaptation options or through development policies to support drought-affected households. Another determinant that cut across all cases was the health status and health services that households have access to. Health stress is related to climate variability but can also be seen as a basic service and need that should be addressed to reduce vulnerability at multiple stages in the chain of drought risk. Off-farm income is important for case studies located in the two countries that are relatively wealthier, Mexico and South Africa. This highlights the differences that national-level policies might have on local impacts of drought on food security.

In many places, the term "food security" is still equated with "food availability." The result is that government strategies to address food security, such as strategic grain reserve programs and various agricultural development strategies, end up addressing only availability. These do not achieve the desired goal of reducing food security because government has not integrated into their policies other key determinants that impact directly on food security. There is the need to develop effective long-term agricultural policies that are situated within a wider development framework. For example, *1*) productive commercially oriented smallholder farming systems that employ cheaper means of enhancing farm productivity could be promoted, *2*) irrigation development for drought mitigation strategies and sustainable food production could be encouraged, *3*) barriers to land ownership and secure tenure could be addressed, and *4*) the capacity of farmers and rural institutions to continue to provide safety nets in times of food crises could be better supported.

The implications of this study for climate policy as related to food security are clear. The impacts of climate change on food security cannot be seen solely as food production issues. Food security depends on livelihood security that, in turn, depends on many factors, including social, economic and environmental determinants. The second key policy issue is that understanding the context is of paramount importance. Depending on the local and national situation, certain institutions support access, availability, and utilization of food. It is difficult to generalize about coping strategies in response to stress. Support for adaptation measures therefore needs to be grounded in the local context. What might be effective and contribute to improving food security in South Africa might be ineffective in Sudan and land up increasing vulnerability of marginal groups. It is therefore critical to verify and screen adaptation options and support.

This paper has highlighted that there are commonalities and differences in understanding food security in light of climate extremes such as drought. In cases in which there are commonalities, more could be done to look at how other countries have managed both the response to drought and the efforts to reduce the impact of drought. A potential increase in drought frequency and increased temperatures requires that understanding these processes of risk are a priority in order to respond appropriately with support for the most vulnerable groups.

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Table 1. *Summary of the Importance of Determinants*

Most important (3 or more ranked as very important)	**Very Important (2 ranked as very important)**	**Important (Ranked as combination of very important and important)**	**All important (All case studies ranked as important)**
Trends in precipitation	Recent drought	2-year/seasonal drought	Ability to subsist
Input price	Area cultivated	3–5 year ENSO	Household size
Income diversification	Size/ labor ratio per hectare	5–10 year Drought	Health
Income	Off-farm employment	Land degradation	Poor training and education
Local community institutions	Poor health services		Poor nutrition and human health
Disintegration of social fabric			

Table 2. *Determinants of Vulnerability Situated in a Causal Chain of Drought Risk*

	Structural vulnerability: • Needs • Wants • Means	**Initiating events:** • Climatic • Economic • Environmental	**1st order Sensitivity:** • Impacts • Exposure	**Consequences:** • Nutrition • Health • Livelihood • Death
Sudan	**Water harvesting** **Land degradation** Deforestation Land pressure Pests & disease Market access **Storage** Market prices Welfare	**↓Precipitation** Drought **ENSO** Early warning	**Area cultivated** **Income/diversification** **Training/education** **Community institutions** Off-farm employment Size of holding Household size	**Health/health services**
Nigeria	Land degradation Deforestation Land pressure Pests & disease **Storage** Market access **Market prices**	**↓Precipitation** **Drought** ENSO Floods Early warning	**Area cultivated** **Labour per ha.** **Income/diversification** Off-farm employment **Community institutions** Training/education	Health/health services
South Africa	Land degradation Water harvesting Storage **Welfare** Market access Market prices	**↓Precipitation** **Drought** ENSO Heat waves Floods Early warning	Area cultivated **Off-farm employment** **Income/diversification** Community institutions	Health/health services
Mexico	Land degradation Deforestation Pests Market access Market prices **Welfare**	↓Precipitaiton Drought ENSO Heat waves Floods Early warning	Area cultivated **Labor per ha.** **Off-farm employment** **Income/diversification** Training/education **Community institutions**	Health/health services

Key: **Bold** = Very important (2); regular font = important (1) from the table above.

Figures

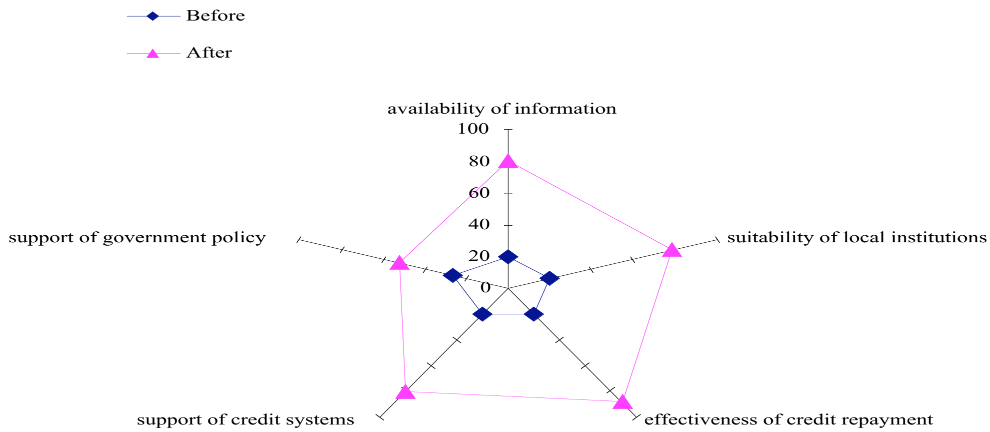

Figure 1: Assessment of sustainability of financial capital before and after intervention of Rangeland Rehabilitation Project, based on availability of information, effectiveness of credit repayment, suitability of local institutions, and support of credit systems and government policy to income-generating activities.

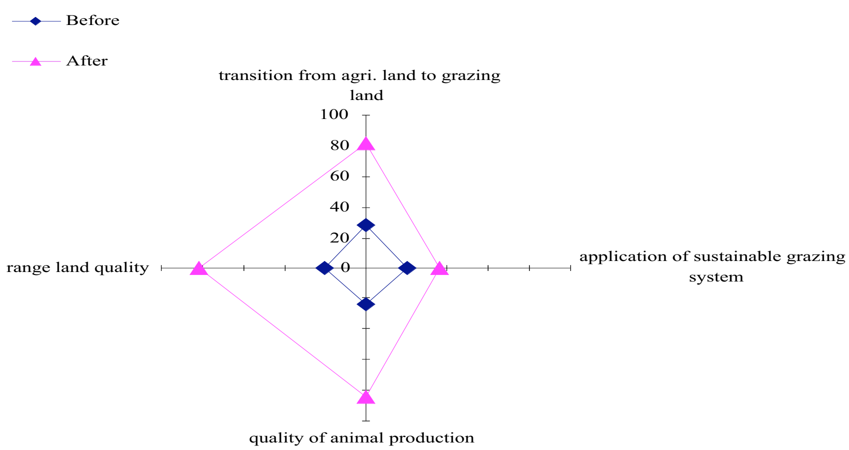

Figure 2: Assessment of sustainability of natural capital before and after intervention of Rangeland Rehabilitation Project, based on % change in four indicators**.**

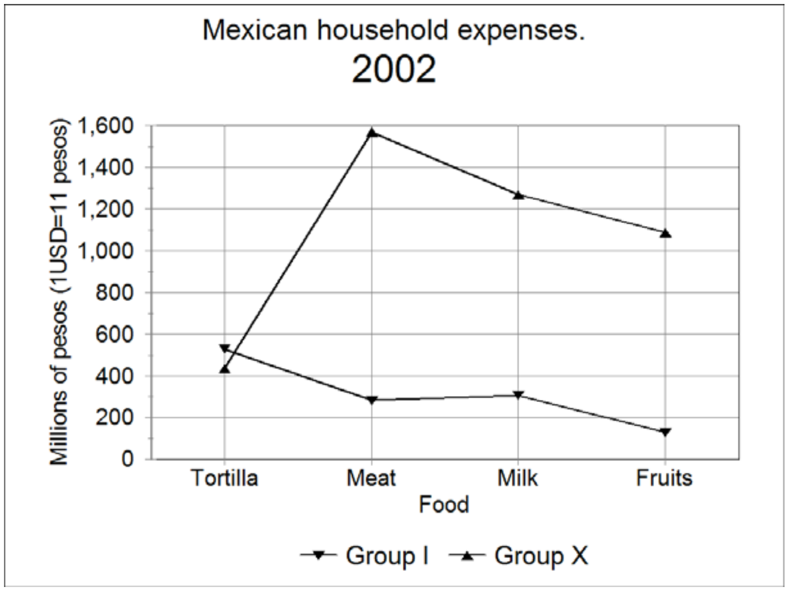

Figure 3. Comparison between the richest (Group X) and poorest (Group I) Mexican household expenses.

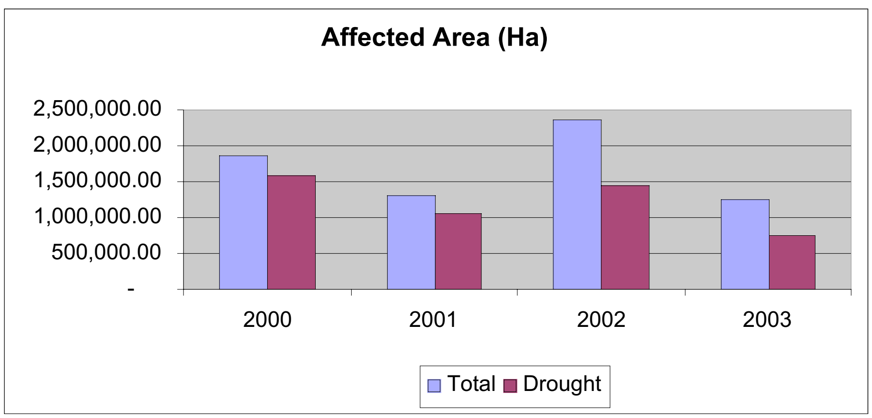

Figure 4: Affected area (Ha) in Mexico during the Period 2000–2003 (Source: Servicio de Información Estadística Agroalimentaria y Pesquera (SIAP) , 2004, http://www.siap.sagarpa.gob.mx/ar_comserhis.html).

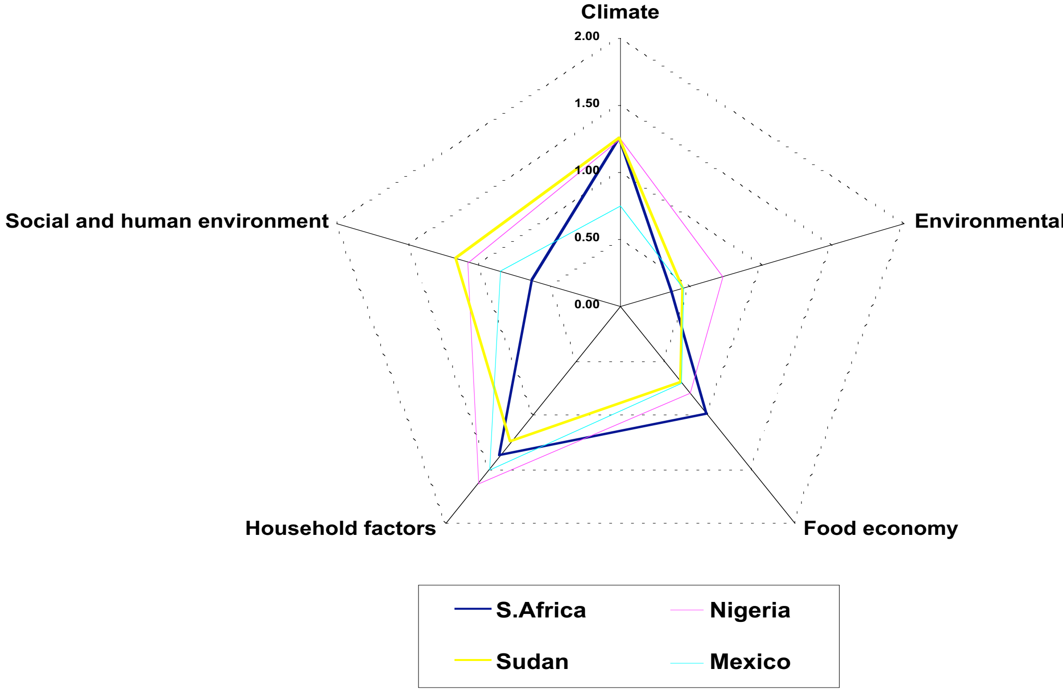

Figure. 5. Determinants of vulnerability to food insecurity in study villages.

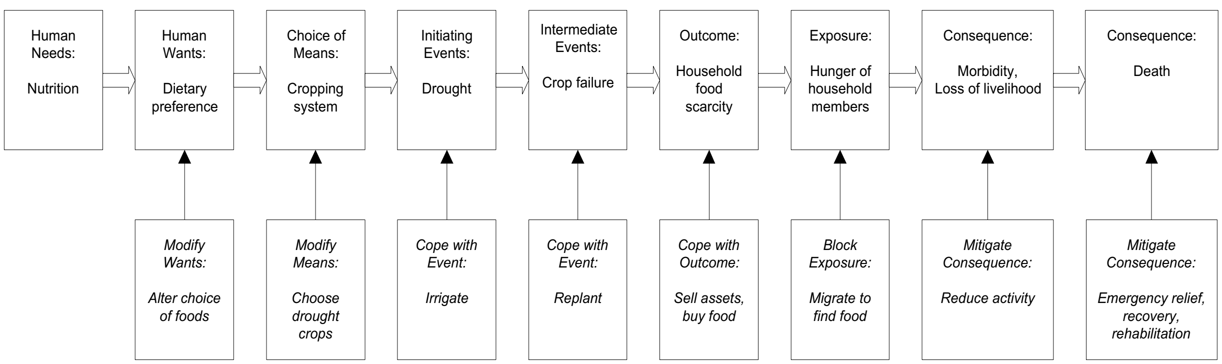

Figure 6. Causal chain of drought risk.