

# *Climate Resilience and Food Security*

## *A framework for planning and monitoring*

June 2013

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#### **June 2013**

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## 1.0 Context

Climate variability and change threaten food security directly—for example, by reducing crop yields—and indirectly, by disrupting the systems and infrastructure people use to access food. Most studies of these issues have so far focused on the impacts of climate variability or extreme climate events on food production. But other aspects of food security such as access, utilization or stability have not received the same attention. As a result, our understanding of the underlying factors that make food systems and communities climate resilient—in other words, able to absorb climate shocks and stresses without experiencing emergency situations—is limited. At the same time, disaster response strategies and policies targeting food security mainly focus on predicting and managing direct impacts of climate events on food production at the local level, and rarely contribute to building long-term resilience, especially among poor communities.

The resilience of food systems is strongly influenced by their complex and dynamic nature. They respond slowly to changes in factors like ecosystem quality, but quickly to prices. Their resilience to climate change becomes increasingly important in a world of growing population, pressure on water supply and unpredictable food crop production. While local food systems remain the primary determinants of food prices and access, in most parts of the world these are also increasingly tied to global markets. Climate impacts in any of the world's major crop-producing regions will have an impact on prices and access to food in most countries. But climate disruptions can also affect transport networks, distribution and storage systems. How much strain can food systems take before they break down? And where are the weak links that are most likely to fail?

A failure of food systems means that people are hungry or malnourished. In addition to the short-term health and nutritional effects and the burden of anxiety created by food shortages, these conditions perpetuate poverty and reduce opportunity for those affected—generally the poorest and most marginalized. Recent analyses of food prices and social unrest on the African continent demonstrate how local food prices are closely linked to drought as a proximate cause, and to social unrest as a proximate consequence. A key conclusion is that stable and resilient food markets are key to avoiding social disruption (Smith, 2013). Will climate change jeopardize the improvements in crop production, marketing and food distribution that have reduced hunger in many parts of the world in recent years?

These questions point to the importance of understanding the resilience of food systems to a changing climate in order to develop appropriate responses. The notion of resilience is relevant at the local level, where it can be used to focus on questions of production, access and delivery of food, and also at the national level, where policy choices can affect distribution, marketing, trade, infrastructure and input choices. But the concept of resilience has not been well defined for food systems, so there have been no conceptual tools or guidelines to help analysts at either level to apply this concept effectively.

In response, this working paper presents approaches to understanding and monitoring food system resilience to climate change. It describes an emerging conceptual tool designed to support analysis of community-level food security and resilience of food systems. The paper begins by establishing the theoretical foundations behind the content of this tool; Section 2 provides an overview of approaches to understanding food systems; and Section 3 examines different approaches to understanding climate resilience. Section 4 lays out the study's conceptual framework and presents a tool to support the assessment of the resilience of food systems. Section 5 explores the application of the concept at the community level, looking first at an analysis of food security and then at an analysis of resilience. The paper concludes with a summary of key findings and identification of next steps.

## About the Project

The ideas presented in this working paper are being developed under a collaborative project in Central America—a region in which food security is a perpetual concern. Food security is already a concern in this region. Central American countries have established early warning systems for food security (e.g., Famine Early Warning Systems Network [FEWS NET])<sup>1</sup> to predict and prepare for times of food insecurity, but these are mostly intended to reduce hunger over short time periods. They are not designed to provide guidance for improving national and local food systems to increase resilience to climate hazards—that is to say, to absorb climate shocks and stresses without local populations losing access to food and nutrition. Moreover, food systems at local, national and global scales are increasingly connected. For example, the impacts of global change on production and global prices for key basic commodities may, in many cases, be as important in determining food security as more localized impacts. As a result, it is important to consider different scales and their linkages when building food system resilience.

With funding from the Climate and Development Knowledge Network, the International Institute for Sustainable Development (IISD) has partnered with Action Against Hunger (ACF-E), the Institute for Social and Environmental Transition (ISET), the National Autonomous University of Honduras' (UNAH) Regional University Centre of the Atlantic Coast, and Central American University's Faculty of Economic and Business Sciences and Institute of Development and Applied Research (Nitlapán) to research, develop and apply a framework for assessing, planning and monitoring climate resilience and food security at the community and national levels. We expect the research results to be useful to two different audiences: national policy actors developing policies and programs to ensure local food security and adapt to climate change; and local project or government staff working directly with communities to strengthen food security in the context of climate change.

Initiated in 2012, the overarching goal of the Climate Resilience and Food Security in Central America (CREFSCA) project is to strengthen the long-term food security of vulnerable populations in Central America by improving the climate resilience of food systems at different spatial and temporal scales. Achievement of the following specific objectives will contribute to this goal:

- Vulnerable communities, policy-makers and development practitioners understand the climate resilience of food systems and have practical tools to measure it.
- These three groups can identify sources of resilience and devise interventions and policies to improve it and measure the impacts of their actions over time.
- Public policies, as well as development programs and projects in the area of food security and disaster risk reduction, take into account and strengthen the resilience of food systems at different scales.

The project applies a new conceptual framework to describe food systems and analyze climate resilience in order to assess the vulnerability of food systems in Guatemala, Honduras and Nicaragua to climate stress. Based on this assessment, it will develop tools to guide communities and national policy-makers in producing their own practical indicators of climate resilience and use those to evaluate the impacts of policies on resilience. The frameworks we

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<sup>1</sup> The Famine Early Warning Systems Network (FEWS NET) is a U.S. Agency for International Development-funded activity that collaborates with international, regional and national partners to provide timely and rigorous early warning and vulnerability information on emerging and evolving food security issues. FEWS NET professionals in Africa, Central America, Haiti, Afghanistan and the United States monitor and analyze relevant data and information in terms of their impacts on livelihoods and markets to identify potential threats to food security. For more information, see: [www.fews.net/Pages/default.aspx](http://www.fews.net/Pages/default.aspx).

utilize emphasize the household as the locus of food security within community contexts that are, in turn, influenced by higher-level regional, national and global systems and institutions.

Because indicators may vary for different contexts and scales, and because understanding and committing to applying indicators is directly related to familiarity with how they were developed, the project tests tools through participatory processes with communities and policy-makers in each country. The guidance tools will help communities develop resilience indicators relevant to their food security context and will provide important information for policy-makers and planners at regional and national levels for developing system-level indicators of climate resilience. As such, applying the indicator guidance tools will provide a balanced mix of information that is relevant locally and to planners and policy-makers at the system level to understand spatial differences within a country. The project is building local and national capacity for assessing food system resilience, but its principal outputs will be these guidance tools, which can be widely replicated for indicator development and planning in other communities and countries.

## 2.0 Approaches for Understanding Food Systems

The term *food system* describes the processes, required inputs and generated outputs involved in feeding a population, including growing, harvesting, processing, packaging, transporting, marketing, consuming and disposing of food (Hawkes, 2009; Sobal, Khan & Bisogni, 1998; Wilkins & Eames-Sheavley, n.d.). Food systems operate within specific contexts represented by available environmental resources, market participation, social interactions and preferences, and by political leadership and governance systems. Frameworks and models of food systems have been developed to improve the understanding of the system, to help structure assessments, to guide policy development and, ultimately, to promote food security and nutrition (for example, food system models by Eriksen, Ingram & Liverman, 2009; Fraser, 2006; Rutten, Meijerink & Chant, 2011; Sobal et al., 1998). However, based on the state of knowledge and specific purposes, we can distinguish four generic approaches to describing food system models (Sobal et al., 1998):

**Food chain** – illustrating the stocks and flows of materials, such as grains, nutrition, water and other resources, that move through food systems and highlight the change and/or transformation that occurs to them during this process.

**Food cycle** – describing the relationships between key elements of the system considering cascading effects and feedback loops such as the buildup of waste products in a field and the water cycle entering and leaving the food and nutrition system.

**Food web** – connecting different elements of the food system to enable better understanding of the consequences of changes—for example, impacts of policies such as tariffs, environmental standards and incentives.

**Food context** – highlighting the relationships between the food system and its surroundings, such as environmental and social systems, represented for example by water and nutrition cycles, community networks and institutions.

The four types of food system models help us better understand the outcomes of the system—that is to say, produced food and its characteristics such as availability, access and utilization. These three characteristics of the outcomes of the food system are directly linked to food security; they have been defined as follows (Eriksen, 2008):

**Food availability** focuses on the physical presence of sufficient food to meet population needs. The determinants of food availability include elements such as production, distribution and exchange, covering a range of specific determinants such as available land, water, pests, land rights and access, labour, skills, tools and technologies for production and processing; access to transportation and information; and markets and market exchanges. Finally, food availability is also influenced by policies and regulations for food production and markets.

**Food access** describes the ability to purchase food depending mostly on available financial resources and prices, types and quantities of food available in markets and/or grown/stored food. It also depends on the preferences of consumers for certain types of diets that could be linked to religious faith, seasonality, advertising, preparation requirements, tastes, customs, gender or age. Determinants of food access thus consist primarily of affordability, allocation and preference.

**Food utilization** emphasizes the ability of the human body to utilize the food that is ingested. It depends on nutritional value, social value and food safety. It can be described by the diversity and quality of food consumed, food preparation practices and hygiene, cultural customs, community and household relations, standards, regulations and practices to ensure food safety at each step within the food system.

Recently, more emphasis has been placed on the spatial and temporal aspects of food security. Specifically, another determinant labelled **food stability** was put forward as contributing to food security (Food and Agriculture Organization, 2011; Schmidhuber & Tubiello, 2007), accounting for both short- and long-term fluctuations in food price or supply. For example, this factor would describe the impacts of extreme weather events influencing production and prices, or changes in food production during the growing season, food storage, fluctuating farm revenues and food prices during the non-growing season.

It is important to identify the unit of analysis for food system studies (i.e., individuals, households, communities, regions or countries) because this determines the spatial and contextual dimensions of the analysis. Based on the definitions above, case studies and approaches published in the literature (Devereux & Maxwell, 2001; Ericksen, 2008), our methodology will start with the household as the locus of food security, but then focus the analysis sequentially upward to the community and national levels, in order to identify key elements of the food system that contribute to household food security at different scales and over time. Looking at household results from the perspective of different scales allows for consideration of communities as functional units of the food system, which points to the centrality of multiple local livelihood options. For example, individual households have the option of producing their own food or producing food or non-food crops to sell or exchange for food, or participating in the labour market.<sup>2</sup> In urban areas, where labour markets are more diversified, households have more livelihood options through development of specialized skills or exchange of services. Across multiple households, these strategies offer diversity and greater possibilities for household food security than a single strategy at the household level.

A community-focused, livelihood-based approach to food security could therefore start from the perspective of food *utilization* in the households, where food security would be conditioned by the social and nutritional value of the food itself depending on *food access* and *availability*. A complete list of potential strategies for food access would include self-production; production of surplus or cash crops for sale to earn income to purchase food; local barter; other income-generation strategies (labour, remittances, credit, social transfers); and food aid. Household food utilization and access is affected by other food system activities linked to food *availability*, such as overall production, processing and packaging, storage, distribution, markets and prices linked to natural resources, built infrastructure and social and governance systems. These elements interact through characteristics such as affordability, preference, safety and fluctuations. The food system activities and the related resources and services contributing to food security are also affected by policies and supporting organizations. These can be important leverage points for introducing changes to build resilience, so our framework should include these as well.

This food system framework is complicated further because many components interact (e.g., production, exchange, and trade influence prices; production activities influence the ecosystem on which productivity depends). The degree of this interaction, and the factors that are most important in determining outcomes, will vary widely depending on the local context. This makes generalization difficult and suggests that any conceptual framework needs to allow for flexible local interpretation to allow focus on different components of the food system as contextually appropriate. With these food system considerations in mind, we next review alternative frameworks for considering climate resilience.

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<sup>2</sup> Note that this means that even subsistence producers are often exposed to global systems through, for example, changing global grain or input prices, migration and remittances.

### 3.0 Climate Resilience Approaches

The Intergovernmental Panel on Climate Change (IPCC) defines resilience as “the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization, and the capacity to adapt to stress and change” (IPCC, 2007). Similar definitions are used in ecological sciences (Carpenter, Walker, Anderies & Abel, 2001; Resilience Alliance, 2007) and disaster risk reduction (United Nations Office for Disaster Risk Reduction, 2012). The origins of the term *resilience* imply strength and resistance, but in its more recent applications in ecology, socioecological systems and disaster management, resilience is understood to require flexibility, learning and change (Adger et al., 2005; Berkes, Colding & Folke, 2003; Miller et al., 2010; Prasad et al., 2008; Twigg, 2007).

Climate-resilient food systems are robust in the face of climate shocks, adapting and re-organizing to respond to stresses, and recovering quickly from extreme events. Resilience of any complex system is difficult to assess in advance because it is not a simple function of individual characteristics of the system, but rather an *emergent* property of the interactions between system elements over time. Of course, after an extreme event or shock, the resilience of a system can be ascertained by comparing the state and function of the system before and after the shock. But this is not much help either for assessment or prescription. Below, we set out some alternative approaches at different scales that could be adapted and then used to gather relevant information for assessing the resilience of the food system in the specific local and regional contexts.

Considering resilience first in its broadest sense—that is to say, not strictly from a climate adaptation perspective—the work of Folke, Colding and Berkes (2003) identified four clusters of factors that help build resilience in socioecological systems. These clusters include: (i) *learning to live with change and uncertainty*, such as learning from crises and developing coping strategies; (ii) *nurturing diversity in its various forms*, such as nurturing a diversity of institutions to respond to change and creating political space for experimentation; (iii) *combining different types of knowledge for learning*, such as building capacity to monitor the environment and building capacity for participatory management; and (iv) *creating opportunity for self-organization and cross-scale links*, such as creating multi-level governance and building capacity for user self-organization.

Another approach to resilience is presented by the U.S. Indian Ocean Tsunami Warning System (IOTWS) (United States Agency for International Development Asia, 2004). This framework and guidelines were developed to assess coastal community resilience to a wide range of hazards such as tsunamis, extreme storms, erosion and resource degradation. This framework looks at impacts of endogenous and exogenous shocks and compares the pre-shock and after-shock status of livelihoods to determine resilience (similar to Alinovi, Mane & Romano, 2009; Guevara Flores, 2012). The IOTWS assessment framework identifies eight different elements of resilience and compares them across four capacity criteria. The eight elements are defined as follows:

1. **Governance:** Leadership may facilitate and implement legal frameworks to provide communities with basic services and build conditions to enhance resilience.
2. **Society and Economy:** Diversification of livelihoods to reduce dependence on coastal resources.
3. **Coastal Resource Management:** Resources are managed to sustain ecosystem services and livelihoods, and initiatives are implemented to reduce risks from coastal hazards.
4. **Land Use and Structural Design:** Planning and structural designs encompass environmental, economic and community goals to reduce risks from hazards.

5. **Risk Knowledge:** Disaster management authorities and community members are aware of risk and hazards; and risk information is utilized when making decisions.
6. **Warning and Evacuation:** The community receives notification and alerts of coastal hazards; they are willing to evacuate; and they have the proper infrastructure for safe evacuations.
7. **Emergency Response:** Mechanisms and networks are established and maintained to respond quickly to disasters and emergencies at community, municipal and national levels.
8. **Disaster Recovery:** The recovery must include short-term and long-term plans to redevelop areas and promote livelihoods. This is done by activities prior to hazardous events to accelerate disaster recovery and by community engagement in recovery processes, including those affecting the most vulnerable.

This framework looks at resilience primarily through the lens of disaster risk reduction rather than climate change. These key elements of coastal resilience are triangulated with key capacities important for livelihoods as defined by the Sustainable Livelihoods Framework (Allison & Horemans, 2006; Department for International Development, 2001). In this way, the framework looks at available capital in the communities, such as physical and natural, technical and financial, social and cultural, and in institutions, such as policy and planning. Approaches focused on coastal communities' resilience were combined with the Sustainable Livelihoods Framework to identify key determinants of resilience and applied in a number of regions, including Indonesia, Sri Lanka, India, Thailand and the Maldives (United States Agency for International Development Asia, 2004) as well as in Honduras (Rivera Sosa, 2009).

Another conceptual framework for climate resilience has been developed by ISET (Tyler & Moench, 2012). This framework is more generalized, allowing it to be interpreted at multiple scales and in varied contexts, even though it was first elaborated for application to cities. The framework itself covers many of the same features as the IOTWS framework described above, but distills the contents into three categories for assessment: *systems*, including infrastructure and ecosystems (or the "what" of an assessment study); *agents* or actors ("who"); and *institutions* ("how," understood as rules in use). Although much of the literature on socioecological systems combines physical, social and institutional considerations within integrated system definitions, this framework intentionally separates these elements to enable understanding and analysis. This framework is built on insights from literature and practice in diverse fields, from engineering and ecology to public participation and institutional economics. For each category of the framework, a small number of key normative criteria were identified to guide assessment (Table 1).

This framework has been applied at multiple scales in urban and rural areas in Asia to provide insight into the assessment of resilience (Moench, Tyler & Lage, 2011; Tyler & Moench, 2012). It provides a simple way to integrate a broad range of resilience factors, but does not prescribe responses. It provides guidance for local analysis, somewhat like the IOTWS coastal communities resilience framework, but it can also be applied at regional or higher scales, depending on the choice of system. For example, in the case of food systems, the framework could be applied at a community level, with an emphasis on production systems or ecosystems, or at a regional level with an emphasis on distribution, processing and exchange. The framework can be used either to guide assessment or to develop indicators, but its application for indicator development presumes that prior assessment has already been undertaken to identify key vulnerabilities and problems that need to be tracked. Whatever the scale or case, the framework provides broad direction and normative criteria, but details will come from the local context. For example, if vulnerability assessment at the community scale has pointed to increasing risk of seasonal water shortages for irrigation systems, then indicator development could focus on this system and related agents and institutions.

**TABLE 1. NORMATIVE CRITERIA FOR RESILIENCE**

<b>SYSTEMS</b>	<b>Flexibility and Robustness</b>	The system can meet service needs under a wide range of climate conditions. Assets can be converted or structures modified under stress to introduce new ways to ensure continued functionality.
	<b>Redundancy, Modularity and Diversity</b>	There is spare capacity to accommodate unexpected service demand or extreme climate events. System components and pathways provide multiple options or substitutable components for service delivery and are spatially distributed to avoid concentrated failure.
	<b>Safe Failure</b>	Failure in one part of the system is unlikely to compromise the ability of the system as a whole to deliver service. The potential for failures to cascade between systems and system components is small.
<b>AGENTS</b>	<b>Responsiveness and Reorganization</b>	Agents are motivated and able to plan and organize timely action when required, including restructuring. Function, structure and order can be restored in a timely fashion after an extreme event.
	<b>Resourcefulness</b>	Agents have access to their own resources or the resources and services of other systems and agents. Priority actions for adaptation can be identified and the necessary resources mobilized for implementation.
	<b>Capacity to Learn</b>	Agents are able to identify and anticipate potential risks. Lessons from past failures and external feedback are internalized and improvements implemented.
<b>INSTITUTIONS</b>	<b>Rights and Entitlements</b>	Access to systems and capacities is assured by equitable rights and entitlements. Collective action is enabled, rather than being constrained.
	<b>Decision Making</b>	Decision-making processes are transparent, representative and accountable. Diverse stakeholders have ways to provide input to decisions. Dispute resolution processes are accessible and fair.
	<b>Information</b>	Agents have access to necessary information in order to determine effective actions and to make strategic choices for adaptation.

Source: Tyler & Moench, 2012

In the context of a climate resilience framework for food security in particular, we want to be able to apply these notions of resilience. At the household scale, we should consider the resilience of household *utilization* and *access* to food; then scale should be expanded to consider the resilience of the livelihood resources and supporting services through which food is made available. Finally, we should consider the capacities and institutional factors enabling supporting organizations and policies to operate effectively. In this way, we can apply the framework from the household to the national scale, and emphasize those factors of particular relevance in each case.

## 4.0 Integrated Conceptual Framework

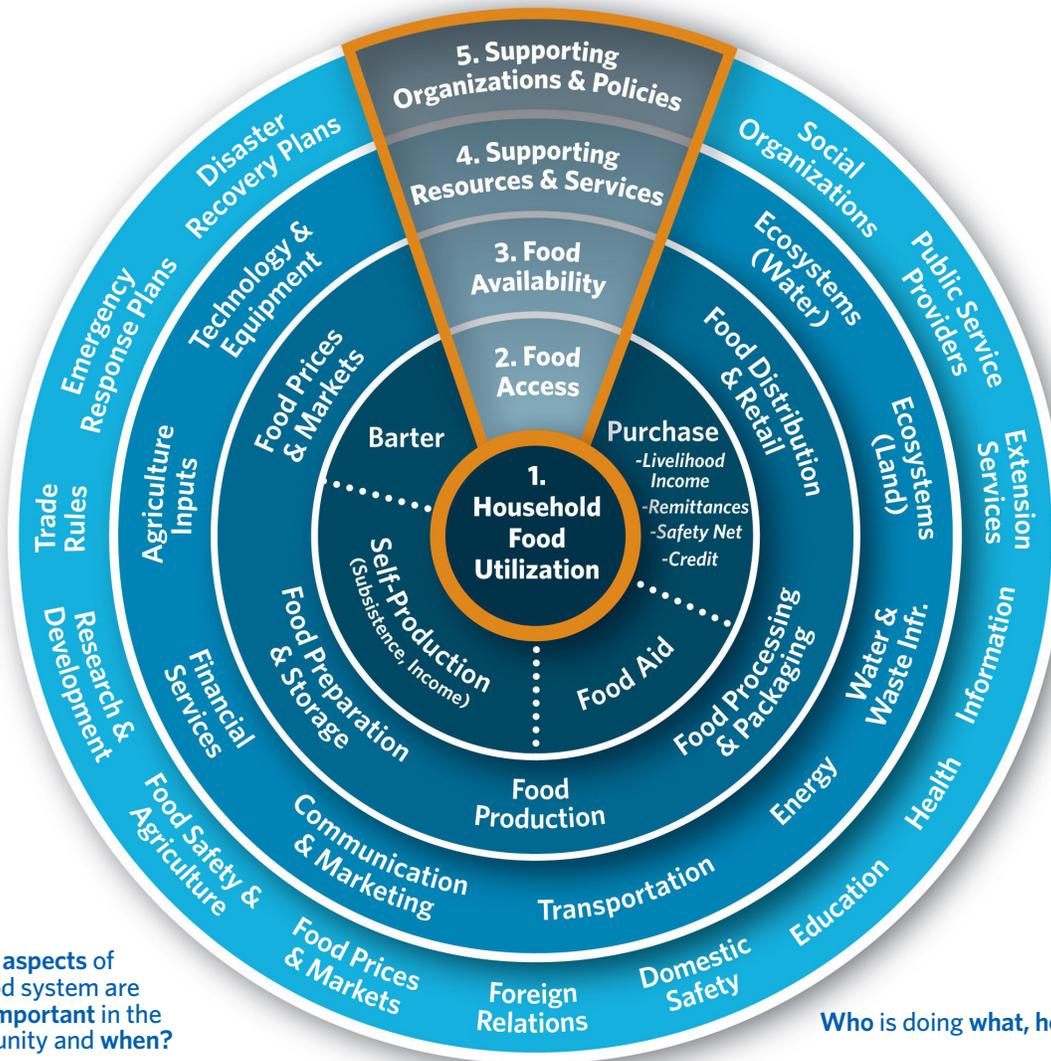
Both the resilience of food systems and wider concepts of climate resilience have been characterized in the literature by direct and indirect linkages, dynamic response mechanisms and emergent features (i.e., many key properties of both concepts actually emerge from system interaction rather than from the inherent character of any one element, such as social assets or agent responsiveness). Conceptual frameworks must accommodate this complexity.

In addition, we have seen that frameworks for both food systems and wider concepts of climate resilience must be flexible to account for variable contexts and scales. System elements or relationships that are crucial in one community (as, for example, water quality would be for aquaculture or fisheries) may be of limited relevance in others. Because we seek to develop indicators of resilience at both the community and national scales, we need a framework that encompasses both. At the same time, we do not want to build a conceptual framework that is too complex and unwieldy. The objective is to apply concepts and tools that can be understood and applied locally, and used to support strategic decision making at the community and national levels.

The subject of analysis for our conceptual framework is food security, so we have built the framework around the key elements of the food system. The household is at the centre of our framework, because it is at the household level that food insecurity manifests in hunger, malnutrition and declining human welfare. To avoid these outcomes under conditions of climate shock or stress, the food system must assure continued food utilization at the household level. The next layer of analysis is around access to food: how the household acquires food through alternative livelihood strategies, and the climate resilience of those strategies. The food access options include emergency food aid, especially because this may be a significant potential source of food security immediately following extreme climate events. Otherwise, the options for food access include self-production, barter or purchase of food.

At the community level, these options remind the analyst to assess *who* is doing *what* in terms of food access. Food purchases may be funded by sales of produce and fish, livelihood incomes (i.e., employment outside household), remittances, credit or emergency “safety net” support from social networks or welfare agencies. Access to food is also influenced by the mechanisms of food availability, including: food production, processing, storage, distribution and exchange. These, in turn, are supported by key resources and infrastructure services, including ecosystems, energy, transport, communications, finance and agricultural inputs. So resilience needs to be assessed at the level of food availability and of supporting resources and services. At the final level of the food system, supporting organizations and policies can serve as leverage points for affecting how supporting services contribute to food availability mechanisms and household livelihood strategies. These could include policies and organizations related to trade, agricultural prices, food safety, emergency response, extension services, etc.

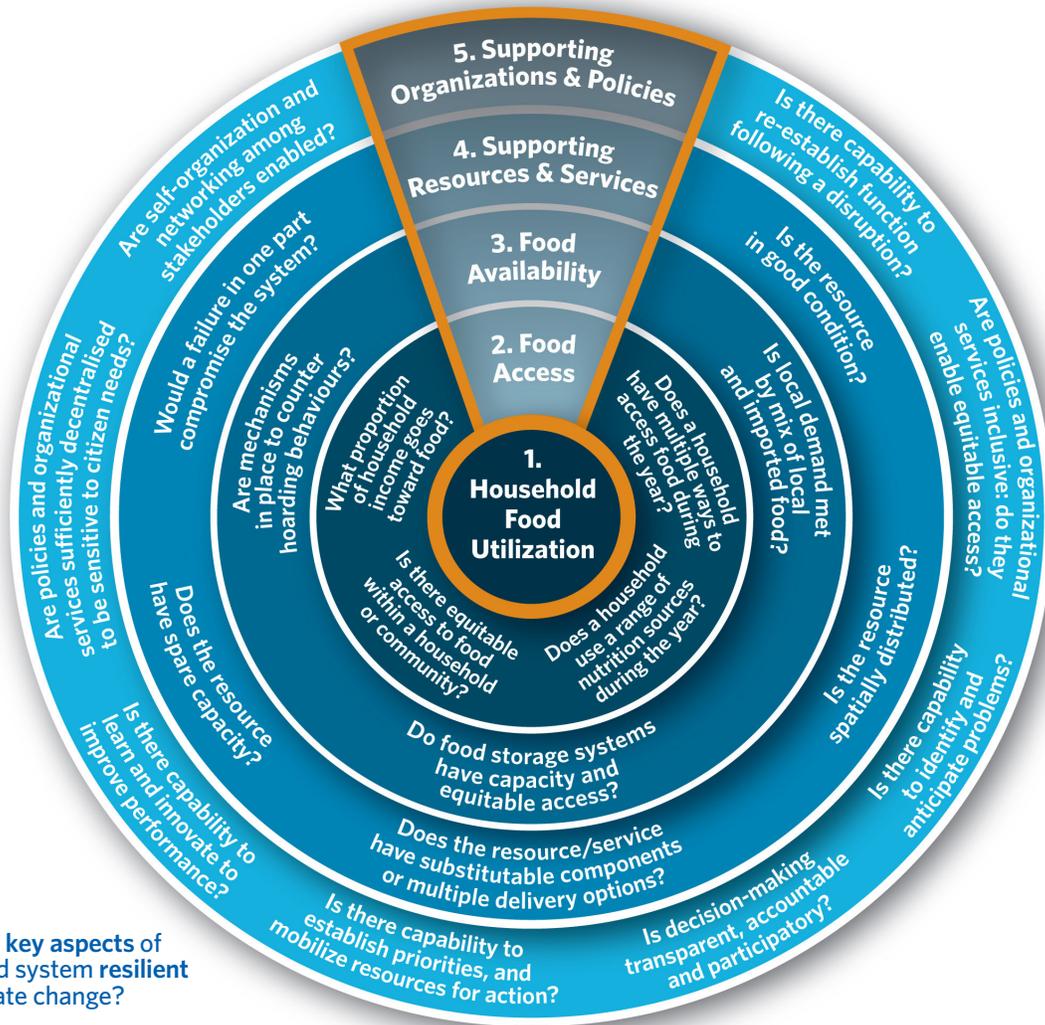
We can simplify this food system representation as a series of concentric rings with the household at the centre (see Figure 1). Note that each ring is labelled as one element of the food system, as described above. Analysis of the food system can start with considerations of food utilization, food access and livelihood strategies at the household and community levels. In any particular community, these strategies may vary; the factors that are most important in assuring food availability will therefore also vary. Similarly, as one progresses outward in each ring, different factors will come into play for each context. Conceptually, one can imagine this process as one in which it is possible to rotate each of these conceptual food system “rings” independently. Users can explore or draw attention to the particular combination of factors of greatest interest in any particular context by rotating each ring to align, or test, each factor in turn. Users may also choose a different unit of analysis than a community. This graphical representation allows the framework to serve as a series of nested “checklists” and criteria for assessment or indicator development, each to be tested in turn, relative to the particular community or scale of analysis. In this case, the framework helps analysts to determine which aspects of the food system are most important in the community, and how they are linked.



**FIGURE 1: COMMUNITY FOOD SECURITY ANALYSIS - SPINWHEEL 1**

We can now identify relevant resilience issues for each of the same concentric food system rings. The difference is that the rings are populated with criteria and questions to be used in resilience assessment.

Figure 2 shows the resilience analysis rings corresponding to those in Figure 1. Users will note that, at the access level, the key aspects of resilience have to do with household characteristics in terms of system criteria (diversity), agent criteria (capacities, especially resourcefulness) and institutions (intra-household entitlements). In the next two rings for food availability and supporting resources and services, system criteria begin to predominate. These rings have mostly to do with the infrastructure and ecosystem services essential for production and handling of food, as well as the institutional structure of market exchange. Finally, the outer ring in the resilience analysis circle draws chiefly on an analysis of institutional factors and agent capacities to assess the resilience of supporting organizations and policies. Thus, the approach mixes the various components and criteria of resilience as appropriate to the food system elements being considered.



Are the key aspects of the food system resilient to climate change?

**FIGURE 2: COMMUNITY FOOD SECURITY & RESILIENCE ANALYSIS - SPINWHEEL 2**

As with the food system rings, these can also conceptually “rotate,” but this feature is less important for the resilience analysis because the criteria on outer rings do not depend so clearly on the priorities or choices for the inner rings. For the food system rings, the analysis proceeds outwards from the centre by identifying crucial system elements and then the supporting resources, services, organizations and policies relevant to those elements. Logically, the analytical focus in the food system rings as you move outwards depends in large part on the choice of key factors on the inner rings. This is not the same for the resilience rings, where all of the assessment questions need to be considered for each layer of analysis; but of course, not all will prove to be significant after analysis. Another difference is that we have framed the contents of the resilience analysis rings as questions rather than categorical elements. This is because, in the food system rings, the various elements are familiar, and the questions that may be asked are contingent on the situation. Resilience, on the other hand, is less familiar, and is mostly about capacities, relationships and performance over time,

rather than specific metrics. The analytical tool prompts users for relevant questions, relationships and investigations in order to reveal weaknesses, rather than to provide descriptive status.

The sequential application of the two analytical rings provides users with a simple tool to assess the complexity of the food system and then to move on to query the resilience of those food system elements. For example, if food access is mainly by a combination of subsistence production and wage labour to purchase food, then a resilience assessment would need to consider whether the access options are sufficiently diverse, whether food allocation within the household is equitable and whether the supporting services for subsistence production (ecosystems, agricultural inputs, markets) are sufficiently resilient to climate shocks and stresses. For purchased food, the distribution system and related infrastructure would need to be assessed in terms of resilience. And the policies and organizations supporting subsistence production and food provision and distribution would also need to be assessed using the questions in the outer ring.

Application of the tool therefore provides a picture of the key elements of the food system and direction as to their resilience. But resilience is not a static snapshot. The dynamics of food system performance are implied in many of the resilience questions, which direct analysts to consider performance over time (decision accountability, response after sudden shocks, linkages between failure in one element and performance of others). Food system elements are, of course, also dynamic, and most elements of the food system also change over time—some quickly, others more slowly. Therefore, the question of resilience at any point in time is not merely the conclusion from analysis of the current state of the food system, but also an assessment of the dynamics of key elements. For example, it is a bigger concern if the capacities of food storage or distribution systems are declining over time than if they are increasing. And similarly, regardless of the absolute level of resilience, it is a sign of growing vulnerability if national systems for tracking the food system and delivering evidence for planning purposes are shut down, or if policy decision making becomes less transparent and accountable. The tool thus provides a mechanism, not only for simplifying and summarizing these complex systems at any point in time, but also for focusing on what aspects are changing and how those changes will affect overall resilience.

## 5.0 Application of the Concepts

This conceptual tool is intended for application in several ways: assessment of the country context, assessment of community cases, and assessment of food system resilience to climate impacts to support development of indicators of resilience at both the community and national levels. The insights that emerge from application of the concepts can assist communities and key actors at national and international levels to identify critical sources of vulnerability in food systems and address them through courses of action that will increase resilience both to the “known” or predictable consequences of climate change and to those impacts that are difficult to predict but inextricably linked.

### 5.1 Country Food System Context and Food Security Analysis

At the country level, the framework can be used to prepare general contextual overviews of the national food system. This first step would then feed into a more thorough analysis of food security and resilience of the food system for each country. The key elements of the food system would first be characterized by the available information at the macro and meso levels, drawing quantitative data from sources such as the Famine Early Warning Systems Network (FEWS NET). This would allow for a relatively simple identification of those factors that have the greatest impact on food security for vulnerable communities and households. Specific analysis of communities and households can be done using CRiSTAL (see Box 1) so the focus here remains at the national and regional levels.

A country-level food system analysis would use the conceptual framework to consider: the main types of foods that are consumed at the regional level; the mix of food access strategies available to vulnerable communities, if possible by region; the related availability factors, supporting resources and services for these access strategies; and the related organizations and policies. The description of these factors would serve as a starting point for further analysis of the relationships and interaction between them, and of changes over time, with special focus on national-level organizations and policies. For each of these elements, this analysis would look at who does what and how. The results of this analysis should point to key factors influencing the resilience of national food systems. These factors could then be the object of the resilience indicators to support monitoring. The analysis will, in particular, provide the focus for policy and organizational capacity assessment, which will point to those factors within the direct and indirect control of government agencies.

### 5.2 Community Food Security Analysis

At the community level, analysis should focus mostly on the nature of livelihoods and resources, as well as how livelihoods and resources interact to influence food access.

The Community Food Security Analysis layer of the spinwheel tool (Figure 1; which we will call “Spinwheel 1” for simplicity) will support the community food systems analysis. The first layer of the indicator guidance tool is designed to gain an understanding of the food system as it is seen from the perspective of the community. The guiding question is: ***Which aspects of the food system are most important to community food access?*** Ideally, the analysis should be differentiated among different social groups within the community (households, gender, age groups, livelihood groups, etc.) to better understand how different groups are vulnerable with respect to food security and climate change within the community. This differentiation of vulnerability assessment may be aided by considering “signature events” within recent memory, such as a flood, drought or crop failure that lead to these kinds of stresses. In the next section of the report, we will explain the Community Food Security and Climate Resilience spinwheel (Figure 2; referred to as “Spinwheel 2”) and how that contributes to the analysis.

This spinwheel tool can be used to support the analyses undertaken both at the community and national level. For the community level, we have revised the CRiSTAL tool to incorporate these climate food security and resilience spinwheel frameworks. As described in Box 1, the CRiSTAL tool uses community consultation methods and a logical progression of assessment questions to draw out the structure of local livelihoods, the resources these depend on, and the impacts on vulnerable groups and resources of climate hazards. The tool currently addresses resilience by highlighting the community's existing coping strategies and points to the resources that are central to these strategies. It is being used with the five rings of the spinwheel framework in order to support community engagement in collection and organization of data on key food system conditions in different communities and to better understand resilience to climate change.

### **BOX 1. THE CRISTAL TOOL**

CRiSTAL (Community-based Risk Screening Tool – Adaptation and Livelihoods) is a computer-based project planning and management tool that helps users to integrate risk reduction and climate change adaptation into their community-level work. This tool is most appropriate for community-level assessments of linkages between climate hazards and livelihoods. More specifically, it looks at:

- How climate-related hazards affect a project area and local livelihoods.
- How people cope with the impacts of these hazards.
- Which livelihood resources are affected by hazards, and which ones are important for coping.
- How project activities affect access to or availability of these critical livelihood resources.
- What adjustments can be made to a project to increase access to or availability of these critical livelihood resources.

CRiSTAL follows a series of logically linked analytical steps and builds mostly on information gathered through community consultations. By placing livelihood resources at the core of the analysis, CRiSTAL implicitly focuses on how the livelihoods of a community can be made more resilient to climate shocks and stresses. CRiSTAL has been applied in a number of countries, including Ethiopia, Kenya, Niger, Mali, Tanzania, Uganda, Zambia, Sri Lanka, Peru, Bolivia, Ecuador and several countries of Central America (Costa Rica, Guatemala, Honduras, Nicaragua and Panama). CRiSTAL is particularly useful for our purposes because its analysis focuses on the community level and it specifically integrates livelihood options, climate hazards and natural resources important for food production.

Source: <http://www.iisd.org/cristaltool/>

The analysis of community food security, following the conceptual framework introduced in the previous section, is described in this section of the paper to illustrate the application of the concepts in practice. As in the conceptual framework, analysis starts at the household level, where it focuses on the *utilization* and consumption of food in the households of the community.

At the household level, food security analysis examines the nutritional sources of the household diet (i.e., types of food consumed): which members of the household have access to which types of food, whether households have appliances for cooking and food storage and whether there are common health issues that would compromise food utilization. These types of issues correspond to the innermost ring on the community food security analysis, Spinwheel 1.

From these issues, the analysis proceeds to the next layer, which deals with the mechanisms and pathways by which food can be accessed by different social groups. The purpose of this layer of the analysis is to distinguish different groups or access paths so that those most likely to be vulnerable to different kinds of climate hazards can be identified. Issues of particular concern here include the different sources of food for the household. If a large share of income goes to purchase food, then it is not just the source of food whose vulnerability to climate needs considering, but also the source of income. This analysis is represented in the second ring of Spinwheel 1.

There are two sets of issues related to food *availability* at the community level, summarized in the third ring. First, for the dominant modalities of food access analyzed in the previous step, how is food made available? Second, where a minority of people is particularly vulnerable to climate disruptions because of their food access modalities (e.g., complete reliance on subsistence production), but this differs from the dominant pattern of access for the community as a whole, how is food made available to this particular group? Food availability factors include: production, processing and packaging, distribution and retail markets, storage and preparation. For households that are completely reliant on subsistence production, only the “food production” and “food storage and preparation” factors are relevant. If households rely on purchased food for a significant proportion of their nutritional input, then this would implicate other availability factors, including food processing and packaging, distribution and retail markets.

The analysis at the household and community levels should distinguish the actions of different agents, which may vary through time. In other words, they should reveal who is doing what, how and when with respect to food provision and use. These issues will be important in assessing socially differentiated vulnerability.

The underlying question addressed in the next analytical layer of the framework is: For the main modalities of food access and availability already identified, what natural and built resources and services are most heavily relied on? For any community, the array of supporting *resources and services* will vary depending on the dominant modalities of food access and availability. For example, a community that predominantly accesses food through subsistence production will rely heavily on ecosystem services such as soil quality and water availability, and perhaps on drainage/irrigation resources. Other resources and services that might be important are communication capabilities to receive weather information and transportation and retail systems to obtain inputs. A reliance on pumped irrigation or drainage would cascade into further reliance on energy systems and transportation to maintain the drainage/irrigation system. The overall analysis within the fourth ring will clarify those supporting resources and services of greatest influence to the community's food system. Once again, it is important to consider who provides these services and how. This will point to key organizations for further resilience assessment.

The analysis undertaken for the four inner rings, following the conceptual framework and facilitated by the CRiSTAL tool, leads to the identification of a set of food access modalities, provision pathways, and supporting resources and services at the community scale. The analysis identifies the most important of these, both in terms of the majority of households in the community and for those groups considered most vulnerable, for the particular community that is the subject of analysis. Given this limited set of the most influential provision pathways and supporting services, the final step in food system analysis is to identify those external organizations and policies that are most important to assuring or improving the function of these pathways and services for food security. These policies and organizations at a regional or national level would be potential points of leverage in influencing community food system outcomes over the longer term. They are described in the outer ring, the fifth ring of Spinwheel 1. As with the previous step, identifying the agents involved (which organizations, groups and individuals are responsible) and their function (how) will be important to assessing resilience in subsequent stages of the analysis.

### 5.3 Community Resilience Analysis and Indicator Development

It is challenging to develop pragmatic guidance on analyzing resilience and identifying and developing a relatively simple set of indicators for key system attributes that provide information on resilience. We have in mind two distinct audiences for the application of resilience indicators: one at the community level (i.e., development practitioners and government staff working at the local level and directly with communities) and another at the national policy level.

In both cases, the indicators are primarily useful to demonstrate changes over time. They provide insight into the dynamics of key factors that will contribute to resilient outcomes. We will need different resilience indicator sets for each of the local and national levels, in part because the relevant system factors vary with scale, but mostly because these different audiences influence different levels of action and have different sets of interests.

For communities in particular, in order for the indicators to be valuable in providing guidance for collective and household decisions, they will need to be simple, clear and relatively few in number. If the indicators require a skilled expert to interpret and analyze, they will probably not be very useful at the community level. At the national level, on the other hand, the indicator set can be more elaborate and include more complex concepts. In both cases, indicators should rely primarily on existing or readily available data sources. Again, the data available to national policy analysts is of a different order than that available to communities (although, with reflection, communities could have access to a lot of relevant data themselves, often qualitative and experiential, but typically not well documented).

The development of indicators will proceed differently at the community and national levels. In both cases, indicator development will start with the food security and national assessments described above. These provide a diagnostic of the current structure of food systems at both scales, and allow for the input of key informants at both the national policy level and the community level in shaping the identification and selection of the most important food system elements. These elements will be different at the community and national scales, but in both cases they can be assessed for resilience using the tool designed for that purpose (Spinwheel 2).

The inner rings of the resilience wheel are more relevant for the household and community levels, while the outer rings are of greater importance for national policy and infrastructure investment. For the community scale, a small number of easily understood indicators with readily available data can be developed to track changes in resilience for the community in general and for vulnerable groups within the community. At the national scale, decision-makers will probably want to track community-level indicators, potentially using wider data sets from national surveys, as well as indicators for national policies, organizations, services and resources that support local food security, as identified in the previous analyses.

Based on the overview of climate resilience frameworks provided in Section 3, we explore below how the resilience analysis tool (Spinwheel 2) can be used to guide resilience analysis at the community and national levels. In each case, we illustrate the process by describing the analytical questions that could lead to specific indicators, although we expect that, in practice, such indicators will be developed collaboratively with users at the community and national scales. In the presentation below, we emphasize the factors that explain resilience. Indicators would be more specific aspects derived from these factors (such as child mortality rates for health status).

### 5.3.1 Food Utilization Resilience Analysis

Starting once again at the individual and household levels, the *utilization* of available food depends on a number of different factors, such as institutional norms, human health considerations, power relations and technology, as described in the food security analysis above. Key resilience questions in relation to food utilization include:

- **Does a household use diverse nutrition sources throughout the year?** Nutritional diversity is a fundamental factor for healthy individuals, and an individual's capability to contribute to the responsibilities of a household are directly affected by health, and consequently, the ability to assist with adaptive responses. In the face of climate change impacts, having diverse nutritional sources makes it less likely that all will be affected at the same time. This is a common risk management approach in complex systems (Folke et al., 2003; Swanson & Bhadwal, 2009; Tyler & Moench, 2012).
- **Is access to food within a household equitable?** Social norms and power relations at the household level can differentiate access and/or the quality of food for individuals. Examples could include the practice of women eating after men, or providing better food to sons than to daughters (potential indicators: ratio of caloric intake of men versus women or frequency of meals missed by gender). Smit et al. (2001) have suggested that equitable access to necessary resources is an important element of adaptive capacity to climate change.
- **What is the health status of individuals and their capacity to absorb nutrients?** Potential indicators, if available, could include parasitic infection rates, or incidence of gastro-intestinal diseases or chronic infections. Infant and child mortality rates may offer a proxy for these factors.
- **What types of storage and cooking technologies are available to household users?** Possible indicators for this aspect could include penetration rates of improved cookstoves, pressure cookers or refrigeration.

### 5.3.2 Food Access Resilience Analysis

At the household level, access to food depends on production and exchange mechanisms (including underlying livelihood system characteristics) and formal or informal social support systems. It also depends on the institutional norms ("rules in use") that mediate relations with markets, social support systems and production systems beyond those directly under the control of the household. So to determine how resilient these relationships are to climate stress, based on the conceptual framework introduced above, we would want to know:

- **Does the household have diverse ways to access food throughout the year?** Greater resilience means balancing household food production and non-farm income sources. In India, for example, joint families often explicitly seek to have one family member involved in farming, one employed in a private business and one in government. This ensures access to diverse and hence more resilient flows of income. Another aspect of diversity in food access is the range of formal and informal support systems that enable access to food sources when household production and income may be interrupted or insufficient. Formal systems include food aid from international, government or charitable sources. Informal systems rely on family or social networks. These networks can include institutionalized forms of credit (e.g., by merchants) or patron-client relations (e.g., with large landowners).
- **Does the community have access to diverse food types and nutrition sources?** As already noted, nutritional diversity is a fundamental factor for healthy individuals. The ability to access a range of food types is therefore a critical aspect of a resilient community.

- **Is food access equitable between households?** Formal support networks, for example, may target specific groups that have been identified as particularly vulnerable (farmers, for example, are often eligible for government drought aid) but miss others who may be equally exposed to drought effects (e.g., small shopkeepers who have advanced credit to farmers but are not repaid when droughts occur). Informal systems are typically not intended to be equitable, as they are designed only for the benefit of those in privileged relationships (e.g., clan members or patron-client relations), and they often require explicit or implicit exchange benefits (e.g., service to patron).
- **What share of household income is used to purchase food?** If a majority of household income is used for food consumption, the ability to access other important services that aid in resilience—such as communication, transportation and savings—is compromised. The higher the share of household income used to purchase food, the more likely that food access will be compromised by any kind of disruption to mobility, health, communication, production, etc. This is a good indicator of precarious food access.

### 5.3.3 Food Availability Resilience Analysis

Food availability depends on local production, regional/global imports and food storage. It also depends on the dynamic behaviour of markets, food processing and distribution systems, and production systems. To understand the resilience of these factors to climate impacts, as described in the third ring of Spinwheel 2, we need to address questions such as:

- **Is local consumption served by a mix of regionally produced and imported foods?** Areas that are highly dependent on imported food may be vulnerable to climate shocks in the supply chain. Conversely, areas that lack access to global or regional production sources may be highly vulnerable to climate events that disrupt local production systems. There is no perfect balance here, but extremes at either end are less resilient.
- **Do food storage systems have sufficient capacity?** An important indicator of resilience is capacity for storage within the system that enables a community to buffer fluctuations in availability and/or prices for key food commodities. Historically, storage at the household level was a key component of food security, particularly for more isolated or self-reliant rural societies, and this remains the case in some areas. As food systems have become more reliant on market exchange and distribution mechanisms, storage in a diverse array of commercial and government facilities has become increasingly important as an indicator of food availability. Storage requirements differ between food commodities that do not require refrigeration (grains, etc.), those that can be frozen with relatively long shelf lives (meat, fish, etc.) and those with very short shelf lives (fresh fruit, vegetables). Increased efficiency and reliability of commercial food production and distribution, combined with the high cost of storage, has led to a decline in local food stocks. Most metropolitan areas in the United States, for example, have only three or four days of food supplies in local storage. The location of strategic storage reserves is also an important issue in assessing vulnerability. In Pakistan, the devastating 2010 floods destroyed food crops, but also wiped out the World Food Programme's strategic food reserves, which had been stored in large, centralized warehouses adjacent to the swollen Indus River and were one of the first facilities affected by the floods. The magnitude and proximity of local and regional food storage, relative to demand, are therefore both potential indicators of resilience.
- **Are mechanisms in place to counter hoarding behaviours or supply failures?** Hoarding in response to perceived shortages or the hope of higher prices can affect food availability in market systems. This response can range all the way up to the national scale (numerous countries banned grain exports in response to price spikes in

2009). Markets can also be disrupted by communications failures. For example, power losses to computerized monitoring of food inventories have resulted in shortages when stock depletion is not automatically reported to higher levels in the supply chain and available supplies are diverted to other demand centres.<sup>3</sup>

### 5.3.4 Resilience Analysis of Support Resources and Services

Supporting resources and services for food security, the fourth ring, includes the basic ecosystems on which food production depends and also the critical energy, transportation, communication and storage infrastructure required for markets and social support mechanisms to function. Questions to ask in the resilience analysis of supporting resources and services include:

- **Is the resource in good condition?** Where natural systems are concerned, the condition of local environmental resources (land and water) is widely recognized as fundamental to food system resilience. Key indicators of resilience at this level include: availability of productive land, availability of irrigation and other water supply buffers (reservoir storage, groundwater), integrity and productivity of foundation ecosystems. The resilience of the built systems that support wider markets as well as exchange and distribution systems is also critical. Without reliable energy supplies and distribution, critical transportation, storage and communication systems will fail. Communications networks are critical: finance, credit, markets and social networks are all essentially communications systems. Without effective backup energy and communication systems, mechanisms for responding to disasters, restoring power supply and meeting emergency food distribution needs cannot be effectively coordinated. Indicators of the reliability, capacity and failure trends in these systems are helpful measures of resilience.
- **Is the resource/service spatially distributed so that it is not completely disrupted by a single climate hazard?** This factor is especially relevant for energy, communication, water supply and transportation infrastructure that is spatially concentrated and could disproportionately impact food security and people's livelihoods, even in other areas, if damaged. Note for example the description of the World Food Programme's food reserve losses in Pakistan's 2010 floods (above).
- **Does the resource/service have substitutable components or multiple options for delivering its service?** To ensure that the indirect impacts of climate hazards are minimized, it is crucial that supporting resources and services are diversified, such as using seeds from multiple seed banks, accessing multiple regional markets or relying on multiple water sources. Over-reliance on single mechanisms for delivery of crucial services can lead to high impacts if that system experiences a failure at any point.
- **Does the resource/service have spare capacity?** Climate stresses and hazards can put disproportionately high pressure on other elements of the system. For example if there is a failure in crop production, there could be very high demand for stored food, food aid or seeds to plant the following season. Water supply is another good example, where it would be prudent practice for reservoir storage capacity to exceed seasonal demand under drought conditions.
- **Is there potential for cascading failures in linked infrastructure services if one element fails?** To limit negative impacts of climate change hazards, it is important to ensure that failure of an individual component will not lead to the collapse of the whole system through cascading failure of linked elements (Tyler & Moench, 2012).

<sup>3</sup> This, for example, was a major problem in the Washington D.C. area when intense storms disrupted power to large areas during the summer of 2012 (D. Kaufman, Director of FEMA, personal communication, July 17, 2012)

With regard to natural systems, an example is protecting and monitoring source quality for drinking water under climate stress conditions. If a water source fails during a drought, that can lead to health impacts, loss of livelihoods and malnourishment. For built systems, an example is ensuring that the failure of one pumping station does not lead to distribution system failure. In the case of flood protection systems, it means ensuring that dike failure under conditions of over-topping can be directed through planned releases into marginal lands or previously designated flood channels and away from valuable crops or settlements.

### 5.3.5 Resilience Analysis of Support Organizations and Policies

When disruptions to food production or distribution and infrastructure occur, the ability of populations to cope depends partly on the responsiveness of support organizations and the policies that enable them to act. This is represented in the fifth ring of Spinwheel 2. On longer time scales, the effectiveness of organizations in designing, maintaining and operating food systems is an important contributing factor to resilience. To assess the resilience of supporting organizations, institutions and policies, the following questions are important:

- **Can the supporting organization or policy restore functionality after a climate-related shock or stress?** Responsiveness is an important characteristic of agents that foster resilience (Tyler & Moench, 2012). An example in the context of water supply would be when a government agency responds rapidly to customer service disruptions or larger disasters, and when these agencies monitor system conditions and devote required finances to maintenance (e.g., leak detection, supply sources). Vulnerability to climate shocks and stresses is also important for policy instruments. For example, in many countries, crop insurance schemes provide an important income stabilizing mechanism for producers (Swanson & Bhadwal, 2009). Such schemes can be vulnerable if claims increase significantly over time due to more frequent hazards, such as droughts, floods and pests.
- **Does the supporting organization or policy provide equitable access?** Marginalized groups become even more vulnerable in the face of climate shocks and stresses if they cannot get access to key supporting services from relevant organizations. An example might be water supply or electricity access—do terms of service provision provide “lifeline” rates for basic service at a lower cost for the poor? Equitable access to necessary resources has been observed as a key determinant of adaptive capacity of individuals to climate change (Smit et al., 2001).
- **Can problems be identified and anticipated?** Supporting organizations and policy instruments that regularly undertake forward-looking assessments are typically better positioned to anticipate change and surprise (Swanson & Tomar, 2009). Therefore, resilient organizations and policy instruments are those that have assessed their future performance in light of projected climate changes (i.e., a hydro-electric company that has simulated the effects of drought on its power supply capability). Indicators of capacity might include emergency response plans or formal climate adaptation strategies.
- **Is decision making transparent, accountable and participatory?** Experience has shown that policy instruments designed and implemented based on public deliberation and consensus solutions are more representative of shared values and therefore more likely to be robust in the face of change (Tyler, 2009). Open and consultative processes are also helpful in demonstrating how the views of different stakeholders were considered in decision-making. Without transparent decision making, negative climate impacts may lead to misdirected scapegoating of those who are not responsible, which fails to resolve the problems.

- **Can priorities be established, plans implemented and resources mobilized?** These measures of resourcefulness all point to higher capacity for resilience (Tyler & Moench, 2012). For example, staffing, networks of influence and budget allocations could serve as indicators of resourcefulness, as could the achievement of planning objectives. Ecosystem management organizations often lack resources for a variety of reasons, including: (a) jurisdictions that cover only portions of the target ecosystems; (b) weak status in relation to other governmental organizations; and (c) inadequate budgets for effective management. Similar issues can, however, undermine the effectiveness of organizations managing key energy, transportation and communications infrastructure.
- **Can failures lead to learning, in order to avoid repetition and stimulate innovation to improve performance?** Internalizing past experiences, avoiding repeated failures and innovating to improve performance are all important characteristics of agents that foster resilient systems (Tyler & Moench, 2012). For example, when water supply managers can integrate the experience of prior droughts, floods or extreme storm events into planning and implementation activities, this demonstrates capacity to learn. A prerequisite for learning is that systems are in place to ensure required performance information is collected and analyzed, and lessons are acted on by management.
- **Is the supporting organization or policy sufficiently decentralized to be responsive to citizen needs?** Supporting organizations and policy instruments that have devolved authority and responsibility to the lowest effective and accountable unit of governance, whether existing or newly created, can increase the capacity to perform successfully when confronted with unforeseen circumstances (Barg & Tyler, 2009). This is an important capability in the face of climate change.
- **Do supporting organizations and policies support self-organization among citizens and sharing of good practices?** Even when organizations play no formal role in food system management or in responding to disruption, the presence and density of community organizations serve as nodal points for social network development and human organization that facilitates creative responses (Roy, Nair & Venema, 2009). For example, in the wake of the 2005 flooding of New Orleans, when government departments and services were disrupted or overwhelmed, volunteers from the local Mormon church were delivering vast amounts of emergency supplies (Lejano & Ingram, 2008).

This layer of the resilience spinwheel can be further analyzed with respect to formal institutions and policies. At the national or even global levels these can frame the behaviour and constrain or enable lower-level organizations to respond. Trade agreements, treaties and the operating rules of international organizations affect food security at local and national levels, for example, to the extent that they set the terms for access to global food markets.

### 5.3.6 *Synthesis*

Resilience analysis of the food system proceeds at these five different levels, corresponding to the different elements of food security, as represented visually in Spinwheels 1 and 2. These tools can aid the analyst by providing a summary of key factors to consider at different levels of analysis. Resilience analysis covers a broad range of factors, but in any individual case would focus on a small number of system elements that had been demonstrated in the food system assessment to be most important in that context. Indicators of resilience would be based on the nature of those elements and outcomes of the resilience analysis, as describe above.

## 6.0 Conclusions and Next Steps

This paper describes an analytical framework and a simple tool to identify the key elements of a complex food system and assess their resilience to climate shocks and stresses. This information is helpful to build resilience in food systems in order to ensure food security in the face of climate change. By developing indicators of resilience that focus on these key elements of the food system, both at the community and national scales, we can help planners, policy-makers and project managers at all levels to monitor changes that will help to protect food security in the future.

Climate change will mean increasing disruption to ecosystems and infrastructure from more frequent and severe extreme weather events, from increased variability and from gradual but fundamental changes like sea-level rise or more frequent drought. These are bound to affect food systems in multiple ways that are, at present, largely unforeseen. While most research to date has focused on the direct impacts of extreme events on food production, other aspects of food systems, such as the services supporting food availability or access, are also likely to be affected. But the impacts from highly uncertain future climate events on complex food systems cannot be predicted with any confidence. Instead, we should try to assess the resilience of these systems to a broad range of anticipated and potential impacts.

Both food security and climate resilience are complex. Both are emergent properties of the food system, resulting from the interaction of many dynamic factors in ways that resist simple linear projection. In order to provide practical guidance to decision-makers at either the community or national level, we must first develop conceptual frameworks that can explain how food security and climate resilience work within complex food systems.

By reviewing the literature in both fields, and applying the field experience of project partners in these areas, we have come up with a synthesis of food system elements and resilience factors that can be represented simply in two spinwheels (see Figures 1 and 2). These graphic tools allow simple representation of different levels of the system or different aspects of resilience, all centred on the household as the fundamental locus of food security. Conceptually, the tools allow for visualization of the metaphorical rotation of the rings to align or compare different factors across levels and scales. In this way, the tools serve as a simple guide to the factors analysts and practitioners should consider at both the community level and the national scale. They remain flexible enough to cover a wide range of local conditions and allow for local users to prioritize different food system elements and resilience factors according to their own context.

These spinwheel tools can be used to support analyses at both the community and national levels. At the community level, a revised version of the CRISTAL tool (see Box 1, Section 5) that incorporates the climate food security and resilience spinwheel frameworks can be used with the spinwheel framework, in particular with the innermost rings, in order to depict key food system conditions in different communities, and to better understand resilience to climate change. National assessment of food systems can also use the spinwheel frameworks to identify indicators and inform policy and planning, but with a greater focus on the outer rings and more elaborate resilience assessment of multiple factors, where the systems are more diverse and of larger scale. At this scale, the analysis will address food system elements and resilience factors that lie mainly beyond the capacity of communities to address. Indicators of climate resilience in the food system will be derived from the resilience assessment at multiple scales, considering, in particular, those elements identified as most relevant in the community or national context.

Through the research, development and application of the frameworks outlined in this paper, we aim to increase the understanding among communities, policy-makers and development practitioners of how the climate resilience of food systems can be monitored and strengthened. This should lead to the development of targeted policies and actions at different scales that increase long-term food security within the context of a changing climate.

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A close-up photograph of parched, cracked earth in shades of brown and tan. In the bottom right corner, a vibrant green leaf with clear vein patterns is partially visible, contrasting with the dry, cracked soil.

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