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Conceptualizing Food Systems for Global Environmental Change (GEC) Research

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ABSTRACT: Food security is underpinned by food systems that encompass all activities from production through to consumption. Across the globe there is mounting evidence that food systems are being undermined, with significant but diverse consequences for food security. Evaluating the impact on food systems of global environmental, economic, social and political change requires a comprehensive and integrated approach. Unfortunately, there are significant conceptual gaps in the theory. The bridge across disciplinary understandings and world views that needs to be made in order to comprehensively analyse food systems has yet to be sufficiently established. These gaps include: analytical separation of the production and consumption sides of the food system; a disconnect between understanding household food security and broader food systems; and divisions among social and environmental causal explanations of food security and other food system outcomes. These gaps are compounded by the rapid rate of change in food systems across the world, which result in highly variable and dynamic situations. An approach to integrate across these gaps begins with mapping food system activities to the broad range of social, economic and environmental outcomes in which they are implicated in specific places. Only through a holistic and multi-scale analysis of these complex systems in a variety of locations will we achieve the integrated and comprehensive understanding necessary to foster truly resilient food systems.

KEY TERMS: food security, integrated systems

Introduction

Food security, defined as when *all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996),* is a policy issue of importance in just about every country. Food security can be considered as the principal outcome of food systems, if they are defined broadly and generically. The increases in the efficiency and productivity of food systems have resulted in remarkable successes around the world in reducing the prevalence of hunger and improving nutrition. However, these successes are shadowed by serious concerns about those aspects of the food systems that pose threats to social, economic and environmental goals and hence undermine food security. In addition, global environmental change, in the context of social, political and economic changes, may bring unprecedented stresses to bear on food systems and food security.

Food systems have usually been conceived of as a set of activities ranging from production through to consumption. However, food security is a complex issue with multiple environmental, social, political and economic determinants. A comprehensive and holistic analysis of how the current organization of food production, processing, distribution and consumption underpins food security requires broadening the concept of a "food system" beyond only those four categories of activities. A host of economic, social, and environmental drivers external to those four groups of activities affect food security as well, and the interactions among these drivers, activities and outcomes are complex. In this paper, I define food systems as including:

- the interactions between and within biogeophysical and human environments which determine a set of activities;
- the activities themselves (from production through to consumption);

- outcomes of the activities (contributions to food security, environmental security, and other securities); and
- other determinants of food security (stemming in part from the interactions in bullet one).

Both food systems and food security in the 21st century are fundamentally characterized by social and economic change. These include the marked intensification of food production, the tremendous growth of processing and packaging of food products, concentration in retailing and distribution, and the rising influence of large numbers of urban consumers. Nutritional concerns have changed with economic growth and change, as diets have altered and the influence of disease is better understood. Additionally, the complications of ensuring stable access to safe food are receiving much more attention. Developing policy to ensure food security is a tremendous challenge that requires a complex and integrated analytical approach (Maxwell and Slater 2003).

Adding to these social and economic trends are concerns that global environmental change (GEC) may bring unprecedented changes to food systems, given the pace at which driving forces are acting and the scale of human domination (Vitousek et al. 1997). GEC is defined as "the net effect of the individual and interactive effects of changes in land use, atmospheric composition, biological diversity, and climate change" (Walker and Steffen 1997). GEC and socio-economic changes are happening simultaneously, and they are both rapid and complex processes involving uncertainty and unknown consequences. Understanding how to manage food systems in this context of change and uncertainty poses considerable research and policy-making challenges. Further complicating the issue is that impact that food systems themselves have on the environment, acting as a driver of global environmental change and creating feedback loops.

Purpose of the paper: a framework for research

This paper outlines a structured framework for studying the interactions of food systems with global environmental change and the major societal outcomes affected by these interactions: food security, ecosystem services, and social welfare. It describes food systems as coupled social and ecological systems (Berkes and Folke 1998), the primary objective of which is to underpin food security, although food systems also have a number of other social, economic and environmental outcomes, and food security is determined by more than just how food is produced, processed and distributed. Food systems are driven by multiple factors, a number of which do not pertain to food security (Cannon 2002); (Pimbert, Thomson and Vorley 2001). The concept of a food system --consisting of components, actors and interactions -- described here is intended to be applicable to any region of the world – Northern, Southern, rich and industrialized, or poor and lagging in terms of economic growth. In building the framework, the paper explores and synthesizes the disparate literatures on food systems, food security, and GEC.

The research framework is intended to be used to develop explanatory understandings of the consequences of dynamic change in food systems for food security. These understandings can then lead to suggested adaptive strategies to bolster the resilience of food systems in the face of GEC. Since the same negative impact can be averted or lessened with more than one approach, food systems analysis needs to identify the various intervention points and adaptation pathways among different actors and institutions and at multiple scales. In addition, as food systems themselves are drivers of GEC, and there is concern about feedbacks resulting from decisions and actions taken in food systems, the framework should enable analysis

over multiple time scales using tools such as scenarios or computer-based decision support models to see what the long term consequences of actions might be.

The outline of the paper is as follows. I first review the trends that have affected both food systems and food security in recent decades. I then discuss how the idea of a system has been used in different disciplines, and why a "systems approach" is useful for analyzing GEC and food security. The remainder of the paper goes into detail on the proposed conceptual framework, which attempts to integrate food system activities with their multiple outcomes and feedbacks to drivers of change. In the conclusion, shortcomings in the current conceptualization are outlined, particularly the complications of spatial and temporal scale.

*Modern food systems and the challenges they pos*e

The wide ranging literature on "food systems" reveals multiple perspectives and a literature that is very much influenced by the world view of the particular author (Sobal, Khan and Bisogni 1998). For research focused on managing or adapting food systems to better accommodate environmental and social concerns, the most useful conceptualizations are those which describe the chain of activities from production ('the field) to consumption ('the table'), with particular emphasis on processing and marketing and the multiple transformations of food that these entail (Heller and Keoleian 2003); (Dixon 1999);(Lang and Heasman 2004); (Cannon 2002). However, most studies fall on one side or the other of a line separating producers from consumers (or supply from demand). The activities central to food systems play critical roles in the lives of both sets of actors, but often policy and other interventions are aimed at only at one of the two groups. For example, agricultural development studies such as Pingali and Khwaja (2004) analyze the food chain in order to identify

interventions which might increase the value added that small holder producers and rural enterprises can capture for themselves, thereby increasing the economic value of agriculture for them as a livelihoods strategy. Lang (2004) and others study the food chain and the tremendous transformations that have taken place in terms of their implications for consumers and shifts in the concentration of economic power. Some of the literature on community food systems tries to bring the food supply side together with consumption in order to tackle the question of how to make food production and consumption more sustainable e.g., Hendrickson and Heffernan (2002). Yet another group of studies focus on the role of agricultural growth and trade in national economic growth (Ruttan 2002)

Regardless of on which side of the supply/ demand relationship authors concentrate, they agree that over the past 50 years food systems have transformed tremendously. Analytically food systems are usefully separated into four areas: production, processing and packaging, distribution and retail, and consumption. The first three are commonly collectively referred to as the "food supply chain". In the area of production of raw materials for food, the major trends have been identified by Maxwell and Slater (2003); Kennedy et al (2004), and Lang and Heasman (2004) as:

- intensification of agriculture and productivity growth due to yield increases,
- an accompanying narrowing of the genetic pool of major crops and animals,
- concentration in the control of agricultural inputs,
- trend to larger farm sizes with hired labour globally, accompanied by increasing fragmentation among marginalized small holders,
- an increase in urban agriculture

- inability for small farmers to support themselves through agriculture alone, and
- increased inequity in infrastructure and information supply.

Added to these are environmental concerns:

- increased demands on water availability for irrigation (Molden and Fraiture 2004),
- increase in pollution from agricultural inputs and soil loss (Pretty et al. 2005),
- an increase in industrialized meat production and a major decline in fish stocks,
- increases in the use of synthetic inputs and commercial seeds and plant stock (Wood and Ehui 2005)
- and a large increase in the energy demands throughout the food production sectors (Matson et al. 1997)

Simultaneously, farming is no longer the dominant economic activity in the overall food system (Lang and Heasman 2004); (Hendrickson and Heffernan, 2002). For example, there has been a huge increase in "value-added" activities in the second area, that of processing and packaging of raw materials into processed foods. The major characteristics of the processing and packaging subsystem are (summarizing (Vorley 2001); (Page and Slater 2004; Reardon, Berdegue and Farrington 2002) :

- an overall increased commoditisation of raw materials (more prepared foods);
- high levels of specialization in tasks,

- an emphasis on standard but exacting requirements for raw foods (shape, size, color) to meet processing requirements,
- an increase in the energy resources used, and
- increased attention to meeting consumer 'demands' for particular products.

As these activities have increased, there has been increasing concentration up and down the food supply chain (vertical integration), as the same corporations buy up companies involved in different aspects of processing and packaging, or form partnerships with one another (Hendrickson and Heffernan 2002); (Boehlji, Hofing and Schroeder 1999).

The third area of activities is distribution and retail, the networks for which have expanded greatly as markets have globalized and transportation routes have improved and extended. Food now travels very long distances (Pretty et al. 2005) as suppliers can source a vast range of goods from around the world so that consumers have access to a variety of cheap goods. This has tremendously increased the carbon costs of food. In principle, global trade increases competition among producers, although in many places market failures prevent producers and consumers from taking advantage of these opportunities. The role and number of supermarkets is rapidly increasing, although with considerable vertical and horizontal concentration among the major owners (Reardon, Berdegue and Farrington 2002); (Lang and Heasman 2004), which is a trend for the retail sector as a whole. Again, this trend decreases the importance of food production overall in the food system, as the retail sector has expanded so considerably and become an important source of profit. It also increases the gap between consumers and producers. Finally, advertising now plays a huge role in the retail sector, as consumers are faced with having to differentiate among similar

brands on the basis of a few characteristics; the creation of consumer demand is a competitive industry e.g. Gallo (1999)

Fourth, there have been similarly significant changes in how food is consumed. In general, food prices have continued to decrease globally. This benefit has not been felt in poorer and more remote areas, however. Growth in incomes has caused a world-wide dietary transition to more meat (with a concomitant rise in demand for grain production), dairy, sugars and oils but there is a simultaneous growth in nutrition concerns about malnutrition in some places and obesity in others, so that there is inequitable distribution of the quality as well as quantity of food, and negative consequences from multiple eating patterns (Popkin 2004). This is exacerbated by the growth in urbanization and a population which relies almost completely on purchasing food (Kennedy, Nantel and Shetty 2004). Food contamination scares have increased because of the heavy levels of pesticides used to grow fruits and vegetables, the dangers of industrialized meat production and disease such as BSE spreading quickly (IFPRI 2003); (Draper and Green 2002). The increase in GMOs has also caused widespread concern over their potential human health consequences.

This is a generalization of global trends, but it illustrates the multiple actors involved in food systems, the broad array of environment and social interactions encompassed in food systems, and the multiple policy challenges posed.

Food security trends

Society still faces a number and range of food insecure situations, with famine as the most extreme case. Most often food security is analyzed in terms of why people do not have it-- i.e. they are hungry or malnourished. The nature of food

insecurity has shifted fundamentally in the 21st century (Devereux 2000). With a greater understanding of the social causes, it appears that famine mortality has declined just about everywhere, and famine has disappeared except from the Horn of Africa, the Sahel and North Korea. (The permanence of this is not yet established and environmental change may increase this risk in marginal areas.) Growth in incomes and agricultural productivity, and improvements in market functioning, along with political will to intervene to prevent famines, has improved food security for many in Asia and Latin America. However, there are still distributional inequities throughout most regions of the world which mean that different groups do not have the same food security status. In Latin America and the Caribbean, incomes have risen in the past 30? years and aggregate food security has improved; however there are still considerable distributional inequities and pockets of food insecurity – e.g. Haiti, indigenous communities in Guatemala, and considerable areas of Nicaragua (Corral, Winters and Gordillo 2000). In Asia the situation is similar, as food insecurity on a large scale has been eradicated (although it still exits in pockets); notably, political will has been as important as economic growth in the case of India and recently Bangladesh (Deveraux 2000), (Dorosh 2001), (Timmer 2004).

In Sub-Saharan Africa food insecurity still persists; the major causes are more than only the impacts of natural hazards or stresses such as droughts (Deveraux and Maxwell, 2001). Economic factors such as market failures and poverty contribute, along with political instability and institutional weakness, and conflicts play a large role, so that now food security crises are routinely viewed as 'complex' (Deveraux 2000). For example, the continuing food insecurity in southern Niger, although due in part to local crop failures on farms that are too small, can not be easily ameliorated because the chronically poor population has no income to buy food, which fetches

high prices in neighbouring Nigeria (Clay 2005). The southern African drought of 2002-3 triggered local food shortages, but a combination of political, social and economic factors prevented market and other mechanisms from getting the available food to people who needed it (FFSSA 2004).

Food security analysis: from availability to access and utilization

Methodologically, the analytical literature explaining food security has evolved since the late 1970s from a focus on national food production and stocks (or the supply of food), which emphasized available food supply at aggregate levels, to a more nuanced and individual-focused approach, which emphasizes access to food along with consumption patterns and preferences, in other words, the demand for food is now considered as very important (Maxwell 2001). One methodological note is that much of the current understanding of why some people are food insecure has been gained from micro- or household level studies, in contrast to a broad systems approach.

Amartya Sen ((1981); (Dreze and Sen 1989)) is universally credited with establishing the importance of access to food, as opposed to only availability, as critical to food security. Sen's explanation that individuals have bundles of entitlements, or resources, among which they can exchange and substitute, helped to analytically frame the notion that access to food was a major determinant of food security. Access is determined by how well people can convert their various financial, political, and other assets into food, whether produced or purchased. This insight explains inequity in food distribution and allocation, based upon income, political and social power. Thus although a country such as India may have ample food stocks, numbers of people are still food insecure because of poverty, low caste

status, inadequate market access, gender and age, etc. In other words, they have less access to food than do other groups (Maxwell and Smith 1992); (ODI 2001). The tremendous growth of urban areas has also spurred a need for a different view of food security, with an emphasis on access and incomes, as increasing numbers of people do not grow their own food, and are in fact quite removed from the production process (Ruel et al. 1998).

Field studies have additionally contributed insights into the temporal dimension of food security, so that transitory food insecurity (seasonal or one event only) is viewed quite differently from chronic (long term) in terms of both its causes and the solutions. Thus stability is also an important part of food security, and seasonal variability in either food supply or income would be considered a potential indicator of insecure food status if trend levels were already low. Additionally, the impact of multiple seasonal shocks can build up over time so that households never have time to recover (Maxwell and Smith, 1992);(Barrett, Holden and Clay 2004); (Le Sage and Majid 2002).

Including utilization:

The public health emphasis on nutritional outcomes has further amplified the food security framework by adding the idea of utilization as important for food security. . This view highlights age, health and disease influences on how the human body can utilize food and its needs for different nutrients, calories and protein (Young 2001); (Pelletier, 2002; (Bank 2006). Utilization is affected by poor hygiene, food preferences and the physiological condition affecting food absorption. Although overall hunger levels have decreased, micronutrient deficiency is still a large issue in India, for example (von Braun 2005). HIV/AIDS is the latest and most devastating

disease to affect nutritional outcomes, as research has shown that malnutrition can exacerbate the progress of HIV-related infections, and that HIV-infected persons require more calories and nutrients to sustain them (Haddad and Gillespie 2001).

In addition, the danger of contaminated food is recognized, as it affects health and nutritional outcomes (World Bank 2006). Contamination can come from multiple factors ranging from washing with dirty water to using spoiled fish to introducing diseases into food as a consequence of modern production practices, as with BSE and beef in Europe. Furthermore, modern food processing has resulted in less healthy foods which, although increasingly popular, contain fats, added chemicals, and high levels of salt and sugar (Popkin 2004)

A result of the diet transition that occurs with growth in incomes, the advent of modern processed foods and increased urbanization, the dangerous impacts of obesity and bad diets have introduced a different set of nutritional concerns (Popkin 2004). With this interest in the health outcomes of food, food security becomes a concept that applies to a multitude of consumers in wealthier countries. Some authors refer to "food poverty" to describe the low quality food available to groups with lower socio-economic status in developed economies; the modern food system has resulted in new but serious inequities of food availability and access ((Wrigley 2002);(Dowler 2004).

Beyond food security to livelihoods

The development of the livelihoods approach to poverty and vulnerability studies has further altered views on food security. The most important point is the recognition that households have multiple objectives beyond achieving and maintaining food security (Swift and Hamilton 2001), so they may go hungry but preserve other household assets. Secondly, in many places agriculture is not the

primary income generator for rural households, for multiple reasons. So the contribution of agriculture to food security must be critically examined. Often people buffer themselves against food and income failures by diversifying out of agricultural production on their own farms (Ellis 2000),(Bryceson 2000). Remittances from relatives working in urban areas, or wages received for working on someone else's farm or in a nearby business are becoming more important sources of household income. A third contribution of the livelihoods approach is the view of the natural resource base as an asset on which people depend for their survival, just like financial, social or physical assets. This acknowledges that the environment does more than just produce food for people; it is also a source of income and a buffer against a variety of biophysical and social/ economic shocks (Scoones 1998). This offers potential for seeking a balance among overcoming constraints and protecting assets, or achieving sustainability (Moorhead and Wolmer, 2001), as other capitals can be substituted for natural capital, or natural capital can be used to support livelihoods in a variety of ways (Ellis and Allison 2004).

Research from the LADDER project (http://www.odg.uea.ac.uk/ladder/), the IDS SLSA project (http://www.ids.ac.uk/ids/knots/projects/slsa/), and the Livelihoods Options project (http://www.odi.org.uk/Livelihoodoptions/default.htm) all highlight a fourth important contribution of the livelihoods approach, which is that the results people are able to obtain from using the various assets at their disposal are mediated by the policy and institutional environment around them. Institutions at multiple levels either constrain or foster household livelihood strategies, and thus food security outcomes, often unintentionally (Swift and Hamilton 2001). For example, in spite of decentralization being a stated policy objective in India, much of southern Africa, and East Africa, the process can still result in local elites maintaining or increasing their

control over important resources such as water and land, preventing poorer or more marginalized groups from obtaining access and thereby diversifying or strengthening their livelihood and food security strategies.

In conclusion, the pressing issues pertaining to food production and food security today have to do with food systems, encompassing a range of economic and environmental and social features that are undergoing rapid change (Maxwell and Slater 2004; Lang and Heasman 2004). Some of the major trends which have shifted during the transition from traditional to modern food systems are summarized in Table 1. On the supply side, raw food materials undergo many transformations and travel long distances before they reach retail markets. Although food insecurity persists in critical areas, globally dietary concerns focus less on under-nutrition and more on obesity and food safety. Income is the primary determinant of consumption and food security status, although distributional inequities are also important. Overall, food systems have become increasingly globalized, interconnected and complex. Hence their interactions with environmental change are not straight-forward.

Understanding Global Environmental Change and its interactions with food system performance

GEC encompasses changes in the biogeophysical environment caused naturally or caused (or strongly influenced) by human activities. These may manifest at the global scale or occur locally but be so widespread that they are a global phenomenon (GECAFS 2005). Examples include phenomena such as changes in vegetation species in a savannah system due to grazing pressure and the absence of fire (Walker and Abel 2002), changes in atmospheric composition from the release of greenhouse

gases and the consequences of these such as increased temperatures (Walker and Steffen 1997), variability in precipitation cycles due to the ENSO phenomenon and other regional patterns (Conway et al. 2005), and the modifications to surface hydrology resulting from the establishment of irrigation systems, dams and other modifications to river flow (Steffen et al. 2003). Thus food systems are themselves a driver of global environmental change (Wood and Ehui 2005) and the future trends in food systems are a concern for ecosystems, particularly as demand for food is expected to increase, with increases in incomes and populations.

A key notion in GEC research is that changes in ecosystem drivers will have consequences for the services that any given ecosystem can then provide, both for its own maintenance and for services such as food provisioning that contribute directly to human well-being (DeFries, Foley and Asner 2004); (Millennium Ecosystem 2003). For example, mangroves may be cut down to make way for fish farms. While this enhances the food provisioning service of the coastal ecosystem, it removes the other ecosystem services of flood control and breeding grounds for native fish species that mangroves provide. Thus trends in GEC and ecosystem services have important implications for the performance of food systems.

With these considerations in mind, the full phenomenon of GEC and its consequences for food systems can only be understood if we look at the interactions between humans and the biophysical environment, the responses the social and biophysical systems make in reaction to one another, and the iterative feedbacks that these same responses cause.

For example, with respect to food production, recent studies (Geist et al. 2005), (Wood, Sebastian and Scherr 2000), (Wood and Ehui 2005)agree that land use modification for food production has significant and wide-spread impact on

ecosystem functioning, biodiversity, and atmospheric composition (Walker and Steffen 1997). Much of this impact has been negative, e.g biodiversity losses have been recorded from land conversion; water availability and access have been heavily modified for agricultural use; intensive agricultural practices have polluted water and soils; human activities have introduced invasive species(Wood and Ehui 2005); (DeFries, Asner and Houghton 2005). Additionally, land use modification and intensive agricultural practices have been linked to GHG emissions (Walker and Steffen 1997). There is also evidence that longer term changes have led to productivity declines in multiple food production systems; for example, losses due to soil erosion, loss of forest cover, decline in pasture quality and availability, water scarcity, and declines in fish stocks.

These combined impacts have raised questions in number of regions about the ability to maintain agricultural productivity, which may have food security consequences as in many places people still rely on locally produced food rather than internationally traded food(Wood and Ehui 2005). All trends indicate that food consumption levels (overall and per capita) will increase, as they have been over the past 50 years, so the question of how sustainable these increases in productivity can be is significant (Ruttan 1999). However, most studies of the impact of GEC, particularly climate change, have only looked at the potential consequences for crop production, e.g.(Fischer, Shah and Velthuizen 2002).

This paper relies upon a framework of food systems in their broader context which uses drivers and outcomes, which is cyclical, and which includes feedbacks and interactions of more than one driver (see Figure 1a). This approach inherently accepts that ecosystems are managed for human benefit; one set of services emphasized (e.g. food production) at the cost of another (e.g. clean water for fish). It adopts the idea

behind adaptive management that an appropriate conceptual framework e.g.(Holling and Meffe 1996); Berkes and Folke 1998) will lead to appropriate decisions. It therefore considers food security and a sustainable environment as important and worthwhile societal goals which food systems affect significantly.

The value of a "systems" approach for applied research

There is a tradition in both the social and biophysical sciences of using the concept of a *system* to help in addressing complex problems with multi-causality (both environmental and social) which result from interactions among components which are interdependent. Often, there is more than one route to an outcome within a system. Another element of a systems approach is that the system of interest can be assessed in the broader context or environment in which it is found, and the impact of changes in these broader environments can be considered at the scale of analysis (Aronson 1996). Finally, systems approaches can also help in understanding the critical factors that lead to particular outcomes or the interactions that govern a specific behaviour of interest (Kassa and Gibbon 200x). Others maintain that systems approaches help to understand complexity because it is possible to identify a small number of key controlling processes, which allow systems to "self-organize" and hence be adaptive and flexible (Holling 2001).

An advantage of framing food systems with this approach is that one can treat them as generic entities with the primary objective of providing food security. The basic categories of activities and outcomes are the same everywhere, but the specific contexts, e.g. market-driven, subsistence, import-based, etc., determine whether or not food security for all is equitably and comprehensively achieved and how.

The understanding of a food system elaborated in this paper lends itself to a "systems" approach as described by (Ison, Maiteny and Carr 1997), in that it is a "problem-determined system" rather than a "system-determined problem". In developing the idea of food systems as complex, heterogeneous over space and time and replete with non-linear feedbacks, the intention is be fully inter-disciplinary, aiming for marriage of natural and social science akin to that suggested by (Scoones 1999) in which he argues that the focus of "new" ecology concerns itself with history, variability, complexity and uncertainty, just as the best social science and policy analyses also do. Thus the paper aims to bring more ecological understanding into the social explanations of food system performance, and vice versa.

Systems approaches in the ecological and social literature

In the field of ecology, the conceptualization of how ecological systems function has evolved from a static equilibrium view to a view in which adaptive cycles, non-linear dynamics and inevitable surprise are critical (Holling, 2001),(Carpenter et al. 2001). This view embraces variation and complexity as inherent to ecological systems and, in fact, as important components for maintaining ecosystem integrity or functioning (this is resilience) in spite of unexpected or large shocks (Holling and Meffe 1996). Much of the research in this area has been aimed at understanding the critical slow processes at which govern the phases of ecosystem change, and how although systems go through fluxes (disturbance then recovery), they are (or are not) able to maintain the basic functions and deliver the same ecosystem services (Gunderson and Holling 2002).

The farming systems research (FSR) approach was an attempt to place agriculture in its broader context and recognize its connections to the surrounding

biophysical, social and economic environment as well as the interactions among farms, outputs and the farmers who managed them (Collinson 2001). The development of agroecology furthered this by re-introducing the importance of ecological dynamics into the understanding of agricultural production systems (Francis et al. 2003). The Integrated Natural Resource Management paradigm placed agriculture into an even broader environmental context and recognizes agriculture as one of a range of ways to manage ecosystems to ensure their beneficial services. Consequently natural resources are recognized as providing multiple functions and services to managers, who themselves have multiple goals. For example, food production relies on managing natural capital for one specific service – food - however this is in a context where there are other demands on natural capital, and farmers and the environment are diverse (Izac and Sanchez 2001).

To understand modern food systems, which include much more than agricultural production, economics is paramount. For the study of macro-economics, economies are often envisioned as systems which may be open or closed, depending upon how much trade and exchange they have with other economies. As trade among nations has grown, an understanding of supply and demand and interdependence between them introduced lots of insight into the economic dimensions of food markets (Jayne and Jones 1997). An understanding of how domestic and international markets are linked, and how changes in trade policy interact with other institutions and policies affecting rural livelihoods is key to studies on the impact of trade liberalization for food security outcomes (Imber, Morrison and Thompson 2003);(Stevens, Devereaux and Kennan 2003).

In the late 1980s, critical writings from rural sociologists about the political economy of food production fostered the concept of a 'food system' as a political,

economic and social structure (Lang and Heasman 2004);(Dixon 1999);(Fine, Heasman and Wright 1996). These studies analyze the connections and interactions among components of the food supply chain to understand the consequences for the farmers at one end of the supply chain. The structure of policy and economic factors and regulations are highlighted, as are the ability of key actors and networks to shape the food system. This work highlights concerns about the concentration of corporate power in agriculture and food production, and the multiple factors other than the provision of healthy and affordable food that drive the food business, particularly the drive for financial profits. Much of the recent work has been driven by the search for alternatives to globalized food systems because of concerns about their environmental, social and economic consequences for at the local level (Hendrickson and Heffernan 2002).

The notion of agricultural systems as both social and ecological (or coupled) is therefore not new. (Folke 2002); (Berkes and Folke 1998)describe coupled social-ecological systems as co-evolved, with mutually dependent and interacting social and ecological components. This is also a promising model for food systems, as Norgaard (1984) first described of agricultural systems as co-evolved social and ecological systems. The more recent take on co-evolved coupled systems has spawned considerable research efforts by the Resilience Alliance (www.resilience.org) and recommendations for analysis. Critical points this approach are: analyzing the patterns of interaction that produce outcomes; recognizing the continual occurrence of feedbacks as critical for adaptation and dynamics; and acknowledging that uncertainty and surprise are the norm, so one is always managing in context of change.

In the notion of systems as used above, I do not mean to imply that every outcome in the world is governed by macro-level or structural features. Individuals

also can make a difference and actors affect change through their agency, or maintain certain institutions by their actions. In complex systems there is an interplay between structure, which is usually at a broader or macro level, and agency, which is local or micro level (Clark 1998). Thus although institutions and structures govern people's actions, the structures are also modified over time as a result of individual actions (Leach, Mearns and Scoones 1999). This evolution in thinking (known as structuration) about social systems has allowed for the recognition of important heterogeneity among households, communities, and institutions themselves. This ability to allow for and accommodate differences among individuals at the micro-level is an important link to much of the more recent research on food security which is household level.

A food systems framework for GEC research

A conceptual framework of a food system suitable for GEC research is shown in figure 1 b. This framework is intended to allow for a comprehensive analysis of the interactions among broadly defined food systems and global environmental change, in the context of socio-economic and policy change. It includes the major activities and actors involved in food systems, as well as the critical processes and factors influencing the social and environmental outcomes that are also part of a food system. A central notion to this framework is that the primary outcome of any generic food system is food security, although in specific contexts food security may not be achieved because actors have multiple objectives, or there are market and other institutional failures, etc. This framework links the production and consumption sides of food systems, as described by Dixon (1999) and Heller and Keoleian (2003). To incorporate the full range of issues discussed in the first part of the paper, the

framework also incorporates food system outcomes that affect the natural resource base, and that contribute to other social capitals or securities such as income, employment, and health. Often decision makers at multiple levels have to choose among different outcomes, as they may not all be equally or simultaneously feasible. These choices or "tradeoffs" can be quite acute.

The framework separates activities from outcomes quite explicitly. This allows recognition of key determinants of food security outcomes that are not directly linked to food system activities, although they may also be influenced by them—for example, income, which could enter the system as a driving force or as one outcome of food system activities for those involved devoting labour or financial capital to them. This distinction among the activities and outcomes also enables a close look at interactions among the multiple drivers that influence food systems—i.e. none of the outcomes is caused by only one driver.

By breaking down the food system into components, and then trying to identify the major determinants of those components (for a given location), I hope to facilitate analysis of whether, when, where, and how a given shock or trend might be affecting one or more parts of the food system. This builds upon the idea that within complex systems it is possible to identify key processes and determinants that control outcomes. Approaches to complex systems such as those discussed in (Geist et al. 2005) and (Walker et al. 2002) also maintain that it is possible to identify these key processes through the rigorous analysis of case studies. Including the activities and the outcomes as part of the system also enables understanding of how the whole food system interacts to create vulnerabilities to GEC in ways that one might not see if you only evaluated the components separately. This also allows the identification of options to buffer against or mitigate the impacts of shocks.

A brief description of the food system components follows.

The food system activities

The food system activities are grouped into four categories: producing food, processing and packaging food, distributing and retailing food, and consuming food. For the most part, different actors are involved in each of the four categories (Dixon 1999; Cannon 2002). The distinctions are blurring, however, as more integration of control and ownership is happening among processing, packaging and retailing actors, so the same actors are key to multiple food system activities (Sundkvist, Milestad and Jansson 2005). There is a substantial literature describing the first three categories as constituting the *food supply chain*, and discussion of the profit margins to be exploited at the different stages.

Producing food includes all activities involved the production of the raw food materials. These range from the process of obtaining inputs such as land and labour, preparing land, breeding animals, planting crops or obtaining young animal stock, caring for the growing food material (including weeding, thinning, fattening, vaccinating, etc), and then harvesting (including wild foods) or slaughtering it. A variety of social, economic, physical and biological factors determine these activities, from land quality to climate conditions, land tenure input prices, agricultural or harvest technology and government subsidy provisions intended to protect or promote production. Key actors include farmers, hunters, fishermen, the multiple suppliers of production inputs including agricultural labourers, and land owners.

Processing and packaging food includes the various transformations that the raw food material (vegetable, fruit, animal) undergoes before it is sent to the retail market for sale. All of these activities "add value" to the raw material in an economic

sense, but these activities may also significantly alter the appearance, storage life, nutritional value, and content of the raw materials. For example, wheat undergoes extensive processing and packaging before it becomes bread. Increasingly the dairy industry involves much more processing and packaging of raw milk (Reardon, Berdegue and Farrington 2002). The determinants of these activities are quite different from those pertaining to producing food, and involve a different set of actors and motives, although the trend is for consolidation throughout the commercial food sector. The exception to this are the regulatory bodies established to control quality and safety. However, many of the standards set in this sector are privately determined, raising concerns about safety and health outcomes (Vorley, 2001), Reardon et al 2002). The key actors are the middlemen who buy from producers and sell to processors; the owners and managers of processing and packaging plants; trade organizations that set standards.

Distributing and retailing food includes all activities involved in moving the food from one place to another and marketing it. Although they are grouped together here, distribution and retailing do not always go hand in hand. Distribution is heavily influenced by transportation infrastructure, trade regulations, and storage requirements. Government redistribution or transfer programs such as food stamps also influence this. Retail is increasingly influenced by how markets are organized, where they are located, and what sort of niche or premium category the product may fit in to (e.g. Reardon et al 2002). Advertising is a significant activity under retailing (Millstone and Lang 2003). Key actors in distribution and retail are supermarket owners, the transportation sector, government ministries that regulate markets, and a range of middlemen who go between the processors and packagers and the final markets.

Consuming food involves everything from deciding what to select, through to preparing, eating and digesting food. Prices are very influential, as are income levels, cultural traditions or preferences, social values, education and health status. As diets globalize and the food system globalizes, the influence of advertising and the structure of the food supply chain also have a large influence on what people choose to eat. The primary actors are consumers themselves.

The food system outcomes and their determinants:

The food security outcomes are highlighted in detail in the framework in figure 1b. The three major categories of food security determinants are access, availability and utilization, as described by FAO (Stamoulis and Zezza 2003), Maxwell and Smith (1992) and Devereaux and Maxwell (2001) and USAID (e.g. see http://www.fantaproject.org/focus/foodsecurity.shtml). The analysis can be made for any unit of analysis, from an individual to a nation. Food availability refers to the amount, type and quality of food a unit has at its disposal to consume. It may be produced locally, imported, or reflect a change in stocks. Availability may vary seasonally or by geographic location, as well as a host of other biogeophysical and socioeconomic factors. Access to food refers to ability of a unit to obtain access to the type, quality, and quantity of food they require. Food utilisation refers to individual or household capacity (including strategies) to consume and benefit from food. This includes how and why it is selected and prepared and utilized by the body, as well as the social value food has in society. Each of these can be further broken down as follows.

Food Availability

Three categories of determinants – production, distribution, and exchange – contribute to food availability. Although familiar to many food security analysts, they have been modified slightly to fit the agenda of describing a food system holistically.

- Production = how much and which types of food consumed (by a given unit) are available through local production. The determinants of availability from local production include seed varieties, land holding sizes, resource tenancy arrangements, irrigation availability, cropping cycle, labour availability, human capital, energy sources, input and output prices, available and adopted technologies, and the control local producers have over their own products.
- Distribution = how food for consumption is made available (physically moved), in what form, when and to whom. The determinants of distribution include transportation and infrastructure, public safety nets, storage facilities, availability of post-harvest processing, governance (power distribution, corruption, whether food has worth beyond consumption), security, and the enforcement of trade barriers and borders (regional and international).
- Exchange = How much of the available food is obtained through exchange mechanisms such as barter, trade, purchase, or loans. Determinants of exchange include income levels and purchasing power, informal social arrangements for barter, local customs for giving and receiving gifts, migration, gender and age structure, markets, terms of trade, currency value, and subsidies.

Access to food:

Three groups of determinants contribute to accessibility of food: affordability, allocation, and preference.

- Affordability = the purchasing power of households or communities relative to the price of food. The determinants of affordability include pricing policies and mechanisms, seasonal and geographical variations in price, local prices relative to external prices, the form in which households are paid, income and wealth levels.
- Allocation = the mechanisms governing when, where and how food can be accessed by consumers. Markets are a key determinant of food allocation; government policies often are designed to correct market failures by allocating food to remote areas or at lower prices. Social capital (as a function of age, class, gender) influences informal allocation processes (e.g., within households), while at a broader scale social/ political capital in urban areas influences where supermarkets are located. Both social and political capital influence rules for fishing, hunting and gathering in rural communities.
- Preference = social or cultural norms and values that influence consumer demand for certain types of food. Determinants may be religion, season, advertising, preparation requirements, human capital, tastes, customs, and female labour force participation.

Utilization:

The three elements of food utilisation are nutritional value, social value, and food safety.

- Nutritional value = how much of the daily requirements of calories, vitamins, protein, and micronutrients are provided by the food people consume. Both over and under nutrition are issues (e.g. World Bank 2006). Determinants of nutritional value include diversity of food consumed, type of primary protein (animal or vegetable), disease incidence (which affects food absorption), education, facilities for cooking and preparing food, access to clean water, and hygiene practices (Sobal et al 1998), (Pelletier 2002),(Haddad and Gillespie 2001)
- Social value = all of the social and cultural aspects of consumption, for example, eating meals together may be an important part of kinship, or it may be very important to always have food for guests, or special foods may be an integral part of important holidays. In some places eating locally or organically produced food is highly valued (e.g. the Slow Food movement). Understanding the determinants of social value requires insight into the community and household relations, as well as cultural customs (Dixon 1999, see also Lang and Heasman 2004).
- Food safety = this is the dangers introduced from the addition of chemicals during production, processing and packaging, and food-borne diseases such as salmonella and CJD. The main determinants of this are the procedures and standards and regulations (or lack of) for food production, processing and packaging.

An example of using these concepts to identify the important determinants of access to food and relate them to the broader food system is shown in Table 2. Here the determinants are in many cases a direct outcome of food system activities, such as production and distribution, but in other cases the determinants are external to the

food system activities, or linked to environmental or other social outcomes such as income.

Other food system outcomes:

In addition to food security, food system activities have environmental outcomes, and food security itself is determined in part by environmental factors independent of the food system activities. The conceptual framework in Figure 2 includes not only the physical stocks of natural capital but also ecosystem services, under the heading of "Environmental capital". Natural capital 'comprises the land, water and biological resources' that people use for various activities (Ellis 2000, p 32). Ecosystem services are the benefits people obtain from ecosystems. They include provisioning, regulating, supporting and cultural services (Millennium Ecosystem 2003). Both natural capital and ecosystem services are inherent initially to any ecosystem, but they are then modified over time.

The determinants of natural capital are largely influenced by the location and geographic endowments; for example tropical forests will have high levels of species diversity but low levels of soil carbon and nutrients, in comparison to temperate grasslands. However, beyond the endowments of a place, management by people largely determines how much of that natural capital is maintained. Similarly, ecosystem services are a function of both geography and management. Thus pasture management, which often involves not only controlling grazing patterns but also controlled burning, can result in the predominance of woody shrubs rather than grassy rangelands, despite the initial or "natural" vegetation. In a pasture system, the incentives to manage for one outcome (grass for animals) rather than the other (woody shrubs) are very much influenced by socio-economic factors such as the prices for

animal products and the tenure regimes controlling access to the pastures (Walker and Abel 2002).

Just as access is important for food security, the framework acknowledges that access to environmental capital is as crucial to outcomes as the stock or state of the ecosystem. This access is mediated by a variety of factors (Leach et al 1999; Young 2002). The notion of "environmental entitlements" extends the premise of political ecology that environmental outcomes are mediated by social, political and institutional dynamics (Leach et al 1999). Just as entitlements to food and power are differentiated by social and political contexts, so too entitlements to the natural resource base are contested, dynamic and differential. The classic example is land tenure.

Much of the food security literature stresses the importance of social and economic determinants of food security, and the framework discussed here has specifically described these in the box entitled "social welfare". These factors are included both as outcomes of food system activities and as determinants of food security. This is an insight from the sustainable livelihoods approach, which acknowledges the multiple objectives of households, communities and governments, and the tradeoffs inherent in decisions made by all of these units. Thus a household may choose to forgo some level of food security in the short term in order to protect other assets such as livestock or land. For those directly involved in the food supply chain, food system activities play a huge part in determining their income, wealth, social and human capital. However, for many others, income and education are determined by non-food system related activities. The framework proposed here allows for both possibilities. The framework also allows health to enter as a determinant of food security outcomes, although the health status of a unit is often

influenced by factors outside of the food system. The same approach can be taken to social capital, which has also come to be increasingly recognized as a crucial element in managing food insecurity, natural resources and other key livelihood elements (Swift and Hamilton 2001),(Ellis and Freeman 2002).

Evaluating the food system outcomes

The three categories of outcomes considered in this framework – food security, environmental security, and social welfare -- are often those among which decision makers at different levels (household, district, nation, or region) make conscious or unconscious choices. There are many ways in which these outcomes can be evaluated, depending upon the perspective or objectives of the evaluator.

This food systems framework is useful for identifying entry points for changing undesirable outcomes, through an analysis of the drivers and activities that resulted in these outcomes. In a companion paper (Ericksen 2006) the *vulnerability of food systems* is described as a state when food systems are disrupted and fail to deliver food security, whether this is due to an overwhelming shock, structural issues, actors in conflict, or environmental degradation. The basic goal of vulnerability analysis is to try and assign causality, albeit complex, and then develop adaptation strategies to lessen that vulnerability. Others may be more interested in the balance among environmental outcomes and food security outcomes, or that between food security and income that results from the structure, processes and management of the food system; they may want to develop interventions to increase a particular outcome.

Ideally using a food systems approach will make explicit where in the system processes are combining to produce an undesirable outcome and help to identify the changes or adaptations that could be made to alter the outcome. As so often these

interactions and the feedbacks they produce are misunderstood or ignored (Sundkvist, Milestad and Jansson 2005), this framework serves a role for researchers and decision makers in clarifying where to focus, with the benefit of an integrated analysis (*cf* Berkes and Folke 1998);(Sayer and Campbell 2001). At a minimum, the analysis encouraged by the use of this framework should provide a platform for multi-stakeholder learning and adaptive management, which can be used along with decision support frameworks and scenarios exercises.

Tradeoffs

There will most likely be tradeoffs among any of the food system outcomes in the short term, and managers and decision makers will also often be concerned with how to resolve those tradeoffs in the longer term. Saying that there are tradeoffs among objectives recognizes that although many social and environmental objectives may often be mutually compatible, in resource constrained situations they are inevitable. For example, in looking at how to set policy to both ensure the viability of farmer livelihoods and conserve ecosystems in tropical forest margins, (Tomich et al. 2005) assess which options there are for "win-win" situations, in which situations both sets of objectives can be maximized, and conversely, under which options conservation can only occur at the expense of smallholder livelihoods.

There is an extensive debate over the relationship between food security and the environment, with earlier work describing them as in conflict (see Moorehead and Wolmer (2001) for an excellent summary). However, recent work recognizes that often there are complementarities between the pursuit of food security and environmental conservation. A more pragmatic view holds that there are inevitable tradeoffs among social welfare, economic growth and environmental sustainability (Vosti and Reardon 1997), which are heightened in the short run. The Millennium

Ecosystem Assessment conceptual framework (2003) notes that the general increasing demand for ecosystem services has added more urgency to resolving these tradeoffs.

A stylized example of evaluating the tradeoffs in food systems is given in figure 2 (adapted from (DeFries, Asner and Houghton 2005)). Here the potential tradeoffs among six different food system outcomes are shown in a spider diagram, and compared between two different hypothetical systems. In the first system, local production of food is enhanced at the expense of the affordability of food overall, and the nutrient stocks in soils also increase. In the second system, food is more affordable but less of it is available from local production; at the same time nutrient stocks of soils have decreased.

Institutions and entry points for adaptation/ interventions

Resolving tradeoffs requires decisions. By emphasizing the importance of social mechanism for ecosystem management, Folke et al (2002) introduce a helpful entry point for understanding coupled systems such as food systems. Institutions and policies are part of the decision-making arrangements that shape the resource management outcome. (Anderies, Janssen and Ostrom 2004; Holling, Berkes and Folke 1998) (Mehta et al. 1999)and (Young 2001) define institutions as rules that structure how people interact with the world around them. Institutions vary in their flexibility and responsiveness to feedback. This understanding is critical for much of the social, political and economic literature on how to improve the policy process, particularly for development and environmental issues. Adopting this view for the study of food systems means that one needs to understand the institutional dimensions of these systems in order to explain the rules governing food system functioning and to identify entry points for change. For example, (Sundkvist, Milestad and Jansson

2005) argue that in modern food systems, the feedbacks from outcomes to activities are not sufficient recognized, and that this leads to inappropriate management with unintended consequences. It will only be through institutional reform, they argue, that the necessary feedbacks can be recognized and managed to avoid negative consequences. Similarly, in their discussion of the impact of trade liberalization on food security, (Stevens, Devereaux and Kennan 2003) emphasize the importance of the local institutional context in determining these outcomes.

Complicating factors: time, space

So far this discussion has not delved into the critical issues of temporal and spatial scale and how they influenced food systems. Food systems as described here are multi-scale with respect to both time and space; hence their analysis must trace these cross-scale interactions. Within a food system there will be feedbacks both from different points in time and from one level (scale) of analysis to another. Scale is important for the analysis of food systems because the scale of observation influences which of a given range of parameters is observed to be more influential on an outcome (Wilbanks and Kates 1999). Thus explanations of cause and effect will vary according to the scale of analysis or level of observation. Scale poses a particular problem for explaining food security, as food security is best understand and evaluated at the household level. However it is governed by food system activities and other determinants which span from the local to the global scales. Most discussions of ecological systems envision them as embedded in scale hierarchies (Holling 2001); this is less well documented for the social side, although some institutional analysts also recognize that institutions and actors are also embedded in scale (e.g. Gibson, Ostrom and Ahn (2000); Young (2001); Berkes (2002)). The scale

of observation can also limit understanding of which variables are endogenous and which exogenous, unless the analysis is deliberately multi-scale.

Note that the diagram in figure 1 is intended to be used iteratively, so one can begin or end anywhere, and the diagram should not be interpreted as hierarchical. The diagram shows the food system at any given point in time or space. However cross-scale interactions are embedded, as the drivers, activities and outcomes will interact across scales. Although one may choose to analyse the food system of a particular unit, one also has to consider that this level of analysis has links to higher and lower levels. This is illustrated in figure 3; affordability at the local level is influenced not only by other local factors such as income, but also regional level gas prices and national safety-net policy.

Perhaps more problematic is that system variability across scales results in heterogeneous outcomes over both space and time, so a given pattern of outcomes will be context-specific. Any conflicts between them will be difficult to resolve with only generic solutions. Scale is also critical because policies are implemented at different levels, e.g. national, district, municipal – and understanding how policies interact either to reinforce one another or, as is more often the case, confound or act at cross-purposes to one another is important to identifying policy or decision strategies. Cross-scale interactions often introduce surprises; thus institutional analysts maintain that unless one figures out the cross-scale interactions they may result in a messy management situation (see Young 2002). Some writers such as Cash and Moser (2000) have focused on how to get a better scale "fit" between social, political and economic management mechanisms and the ecosystem processes that are being managed. Sundkvist et al (2005) maintain that distance in space and time is a large reason that the feedbacks upon which food system management ought to be based (in

an adaptive manner) can be ignored or are masked. This is even more critical given the extent to which modern food systems depend upon cross-scale subsidies. Cross – scale subsidies are very common in food systems (Carpenter et al. 2001); for example food is imported from one location to another, across spatial scales, and increased agricultural productivity today may be at the cost of sufficient water availability in the future. Thus cross-temporal analysis is also an issue because so many tradeoffs involving ecosystem services are between short term gains and long term costs. Another dimension is the importance of stability over time to ensuring food security (Maxwell and Smith 1992). A diversity of sources and strategies is necessary because of the seasonal heterogeneity.

Conclusions

This elaboration of how to describe food systems in an integrated fashion leads to several conclusions. First, to understand a system holistically it is necessary to describe and analyze not only the components parts and actors, but the interactions among these parts and actors that produce variable outcomes. A goal of the system's description is thus to explain the patterns of interactions among the activities, external drivers, and the outcomes, so as to fully assess any emergent properties, as well as cause and effect. Thus, while I accept the inherent complexity of integrated food systems, I believe that a systematic approach to their analysis, through the use of case studies, can reveal critical processes and factors that govern their complexity. However, without an adequate treatment of cross-scale interactions over space and time, the analysis will fail. The second conclusion is therefore the need to treat food systems as multi-scale, even if the outcomes of interest are focused at one scale in particular, for example regional.

Third, as food systems are coupled social and ecological systems, institutions play a key role in mediating between the social and ecological processes and resources. In light of this, this framework is intended to help the multiple managers of institutions to better understand the nature of coupled food systems. It is intended to create new knowledge that is appropriate for social learning and adaptive management.

Fourth, this investigation has required integrating across disparate literatures which rely on quite different methods and have different goals. For example, much of the ecological systems literature seeks to identify critical parameters, while food security literature looks for root causes, and food policy literature wants to identify key issues for policy resolution. I have tried to find common ground but recognize that are still some incompatibilities which may complicate analysis: most critically, the understanding of individual agency versus systemic properties in determining outcomes, and identifying the key institutions with which to work to bring about change.

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Figure 1a: Food systems and their drivers

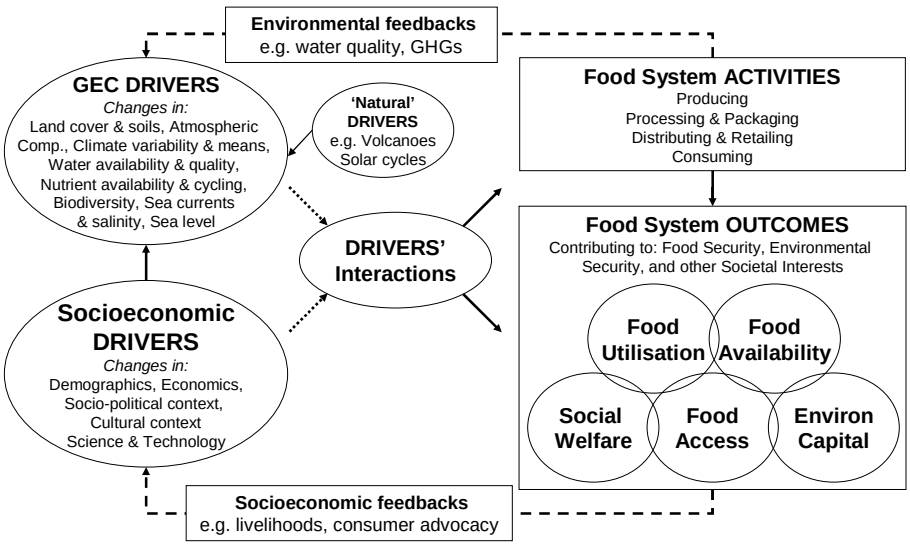


Figure 1b: Components of Food Systems

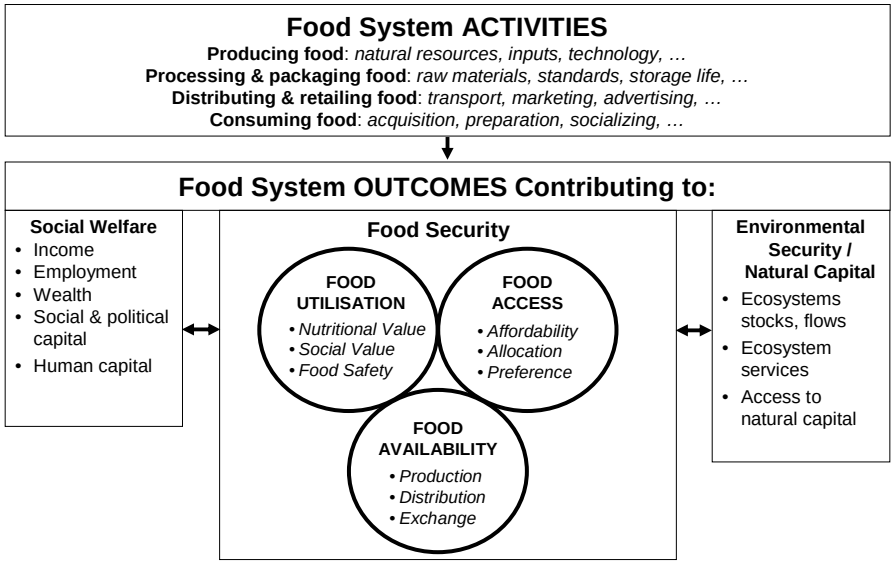


Table 1: Comparing traditional and modern food systems

	"Traditional" Food Systems	**"Modern" Food Systems**
Employment in food sector	In raw food production	In food manufacturing and retail
Supply Chain	Short	Long with many food miles and lots of nodes
Typical food consumed	Basic staples	Processed food with a brand name; More animal products
Purchased food bought from	Small, local shop or market	Large supermarket chain
Nutritional issues	Under-nutrition	Chronic dietary diseases
Main source of national food shocks	Poor rains; production shocks	International price and trade problems
Main source of household food shocks	Poor rains; production shocks	Income shocks leading to food poverty
Environmental concerns	Soil degradation, land clearing	Nutrient loading, chemical runoff, water demands

Source: adapted from Maxwell and Slater, 2004.

Table 2: Linkages between food system outcomes and activities

Access to Food	**Characteristics of food security outcome for Site X**	**Major Determinants of food security outcome**	**Linked to FS Activity? Or Other Outcome?**
Affordability	Staple grains are cheap if imported; expensive if local.	Costs of local production higher than foreign.	Determined primarily by the activities under Producing.
	Fruits and vegetables cheap and available in rural areas.	Increasing numbers of farmers moving into horticulture so is surplus.	Determined primarily by the activities under Producing.
	Fish and beef are luxury foods. Chicken is every day food in urban areas.	Fish increasingly scarce because waters over-fished. Beef is for the export market. Poultry is a new growth sector and so is available everywhere. Processing centered near urban areas.	Incomes differences between urban and rural areas important (social welfare). Aquatic systems reaching their threshold (natural capital). Beef and chicken price and availability determined by Producing, Processing and Retailing.
Allocation	Most food only available in supermarkets.	Supermarket chains dominate in urban areas and local markets have been driven out of business.	Retailing.
	Few markets in rural areas.	Roads in bad shape. Major markets are in the cities. Lack of local transport.	Roads determined by physical capital (social welfare). Incomes and lack of transport

			service from government also under social welfare. Markets in cities due to economic structure.
Preferences	Imported wheat flour preferred in cities to local maize flour.	Advertising; new preferences for convenience foods.	Determined by Retailing and Consuming.
	Fish and beans are traditional foods.	Fish traditionally plentiful; beans also grown locally traditionally.	Determined by social welfare and social value of food.
	Young people like burgers from fast food chains.	Advertising	Determined by Retailing.

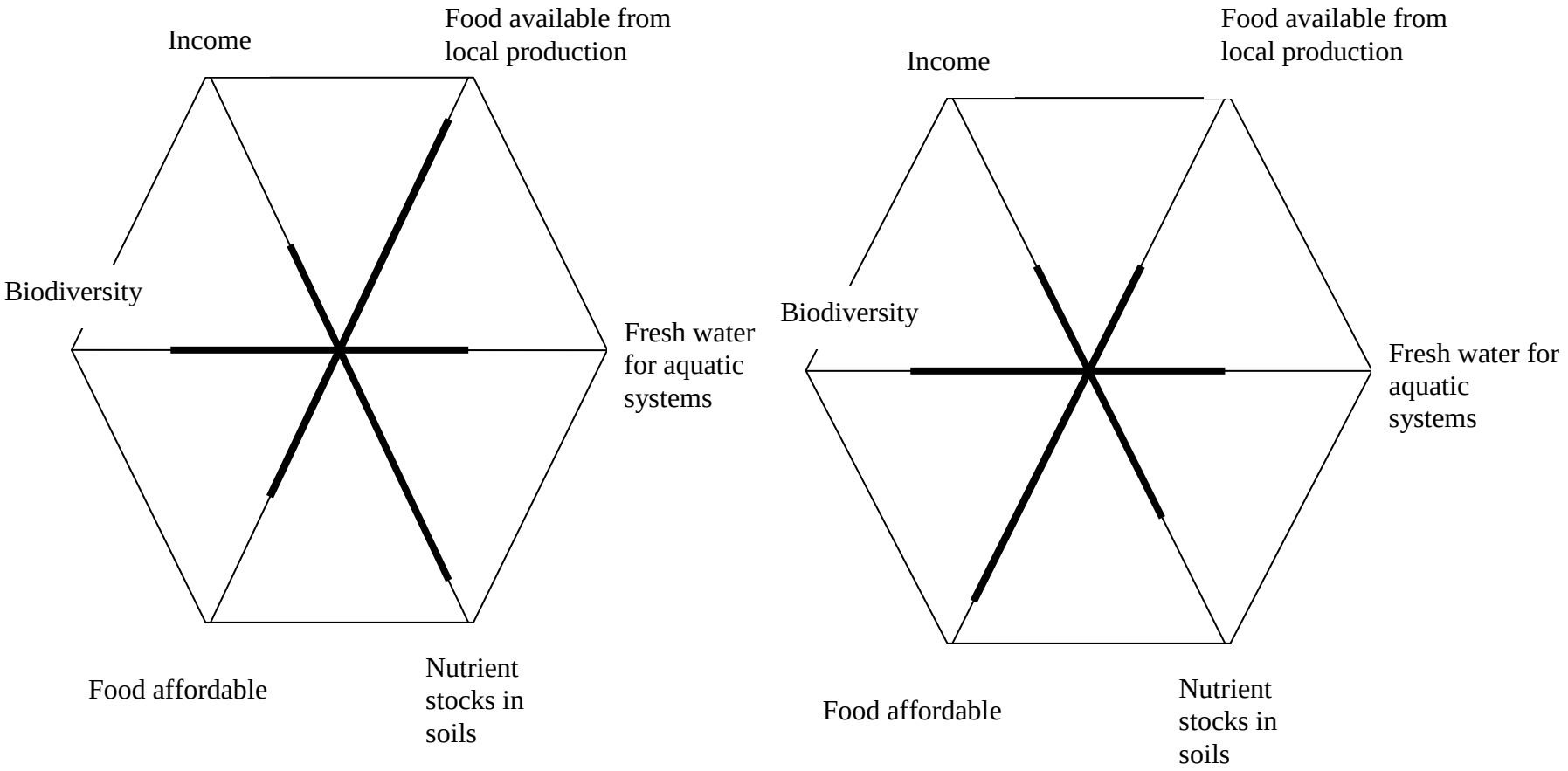
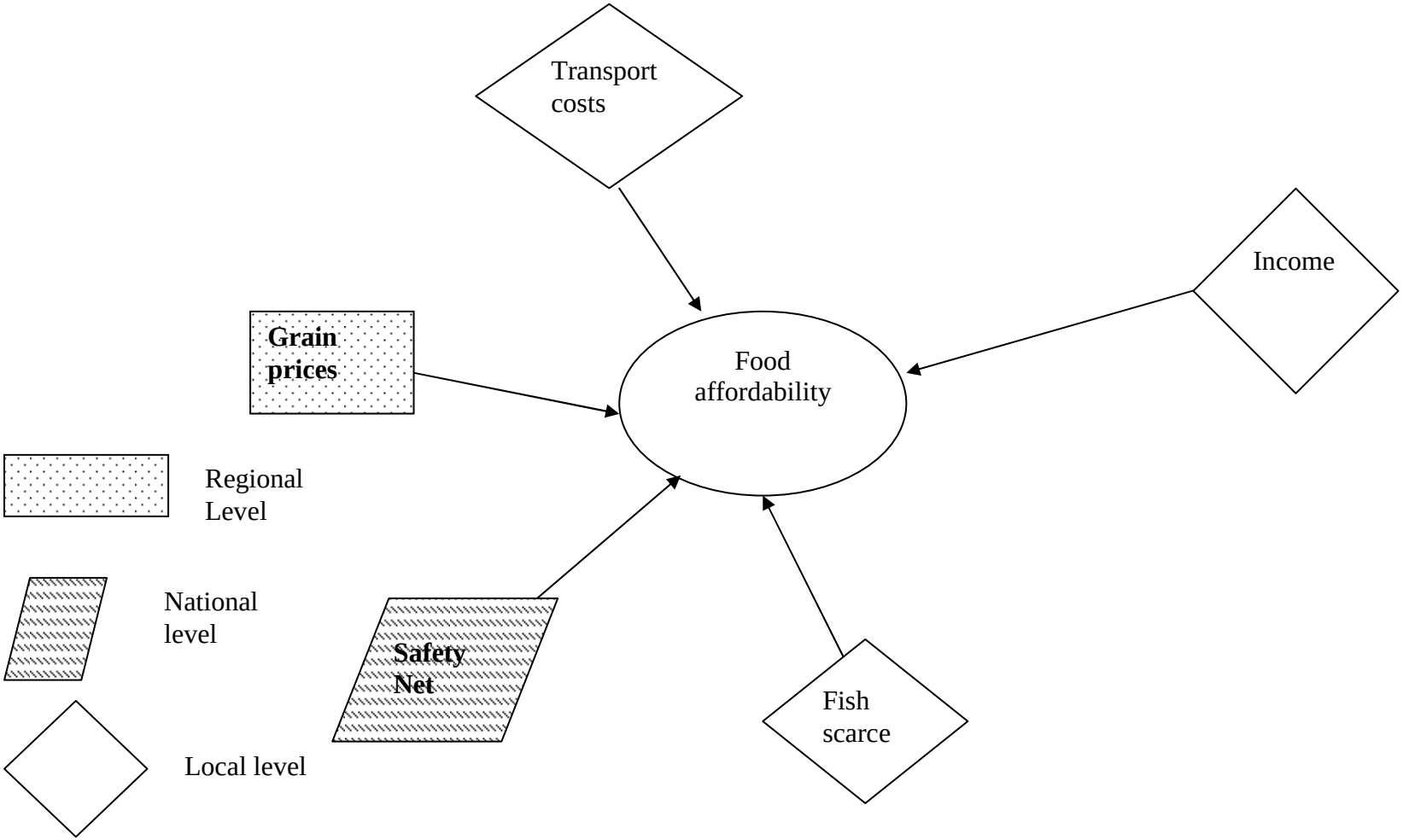


Figure 3: tradeoffs among outcomes for two different food systems.
(*after de Fries et al 2005*)

Figure 4: Cross-scale linkages in food systems



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