Feeding the Future's Cities: Challenges in an Uncertain World

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Abstract

Many areas of the developing world are experiencing a massive inflow of people from rural areas into urban areas. In some countries, this is giving rise to "megacities," cities with 10 million inhabitants or more. The growth of some of the megacities is not in response to economic opportunity (i.e., a surplus of jobs), rather, it is a matter of basic survival prospects and often results in people merely swapping rural poverty for urban poverty. One of the biggest challenges facing these megacities will be providing access to sufficient and nutritious food.

We present a paper in response to the Food and Agriculture Organization's topic of "Understanding complex food systems meeting urban food needs – methodological approaches and disciplinary contributions." Specifically, we will (1) briefly examine the rise of megacities and compare and contrast some of the challenges facing them in developed and developing countries, (2) examine the connection between food systems and community resilience, (3) examine how external events such as climate change and political conflict can impact the food and community nexus, and (4) discuss approaches on how decision support tools can be used to assess the system issues associated with meeting food needs and how vulnerabilities in the food production and distribution networks can be assessed in order to support the food and community resilience cycle.

1. Introduction

The problem of access to nutrition is a growing problem across the world. The breakdown of the food systems cycle not only impedes access to food, but also impacts the overall community resilience cycle. These breakdowns ultimately result in both individuals, and the community they comprise, failing to thrive and become resilient to the larger challenges of life. These failures can be found in *both* the developed and the developing world.

Many areas of the developing world are experiencing a massive inflow of people from rural areas into urban areas. In some countries, this is giving rise to "megacities," cities with 10 million inhabitants or more. In 2014, there were 33 megacities around the world in both developed and developing countries and there a number of areas that are growing quickly and could become future megacities. According to the United Nations, one out of every two children born in the future will grow up in an urban environment (United Nations, 2014). The growth in some of the megacities is often not in response to economic opportunity (i.e., a surplus of jobs), but is a matter of basic survival prospects and simply results in people swapping rural poverty for urban poverty. One of the biggest challenges facing these growing urban areas will be providing access to healthy and nutritious food at the caloric volumes required to support expanding populations. Booming urban populations will place greater pressure on a food supply-demand balance that is already under stress in many regions of the world from environmental pressures or conflict

Table 1 gives an example of megacities from around the world, selecting at least one from each major region of the world (the Americas, Europe, Africa, Asia, and Oceania) and compares them using data elements from the United Nations (UN) Human Development Index (HDI) project (UNDP, 2014). The HDI rankings, which are a composite statistic of four indicators used to rank countries, in the second column are for the 198 countries assessed in the UN data and the qualitative developmental categories used by the UN of "very high", "high", "medium", and "low". The HDI data noted in Table 1 are country level summaries and are presented for comparative purposes only as they may not be representative of the conditions in the noted cities.

Table 1. Representative Megacities and Human Development Index Data (UNDP, 2014).

City, Country	HDI Ranking (Out of 198)	Life Expectancy at Birth (Years)	Under 5 Years Mortality Rate*	Maternal Mortality Rate*	Gross National Income Per Capita ($)
Tokyo, Japan	17 Very High	83.6	3	5	36,747
Jakarta, Indonesia	108 Medium	70.8	31	220	8,970
New York City, USA	5 Very High	78.9	7	21	52,308
Karachi, Pakistan	146 Low	66.6	86	260	4,652
Dhaka, Bangladesh	142 Medium	70.7	41	240	2,713
Sao Paulo, Brazil	79 High	73.9	14	56	14,275
Lagos, Nigeria	152 Low	52.5	124	630	5,353

*Per 1,000 live births

In any area of the world, weaknesses in the food cycle may exist; such as, accessibility, affordability, and quality. In the developed world, where regional food supply may be sufficient, "food deserts" may nevertheless be found where problematic infrastructure, inadequate supply chains, and socioeconomic barriers result in the insufficient or unequal distribution and access to healthy food. Globalized logistics have permitted mobilization of world food production to help meet such local shortfalls, but the overuse of this expedient can have negative consequences, decoupling cities from their own agricultural hinterlands and marginalizing and crippling local primary food production sectors. The resulting deficiencies in food security will also have larger implications for a community's abilities to provide basic services and opportunities, especially at moments when these are most needed.

2. Defining Community Resiliency

It is acknowledged that the literature abounds with numerous definitions for resiliency and that they can vary depending upon the system under study. For the purposes of this work, we define community resiliency as "the ability of a community to anticipate, resist, absorb, respond to, adapt, to, and recover from either natural or man-made events." This definition is based on one used by Argonne National Laboratory in its analyses of the resiliency of infrastructure systems (e.g., Hummel, 2014). It is also consistent with that used by the United Nation's (UN) Food and Agriculture Organization (FAO, 2014).

For the purposes of this paper, we are also taking a broad view of what constitutes a "community." In our definition, a "community" can be represented at many functional levels, from a national level as well as at much finer levels, such as individual cities or even neighborhoods. However, in adopting that broad view, we do not mean to imply that analyses done at a national level will by definition apply to small demographic levels within that nation-state. In fact, analyses at differing scales will elucidate challenges inherent to those granularities, and therefore, indicate appropriate actions that could be instigated.

Figure 1 shows the basic characteristics that contribute to community resiliency as used by Argonne researchers (Hummel, 2014). Again, the literature contains different terms and definitions for the resiliency characteristics, but they all generally share common themes: being able to meet the basic needs of the community; having the will to improve the quality of life; having the services and functionality to make the improvements; and being able to maintain and secure the improvements. The degree to which a secure environment is maintained can also be considered to be a measure of the stability in a community.

Figure 1. Characteristics that Contribute to Resilient Communities.

3. Systems Level View of the Food-Community Resilience Cycle

At the highest conceptual level, the connections between food and community resiliency is understood as a circular relationship – people require food and people who are stronger and healthier will make a community more resilient. A more resilient community enables the residents to be able to be more productive and able to generate or obtain better and healthier food. The FAO states that good nutrition is a critical input for resiliency and a logical outcome of a resilient community (FAO, 2014).

Figure 2 gives a system level view of elements that contribute, positively or negatively, to a resilient community. The elements shown are high level representations of the systems that contribute to a resilient community. The systems can be broken down in to finer level sub-systems and/or combined with other systems to represent more complex concepts, such as an "economy." The result of these contributing systems is that any analysis of resilient communities must be done as a "system-of-systems" problem.

The systems in Figure 2 are fairly obvious in their role and functioning, but a comment is warranted for the "human landscape" system. This system represents the human players that must be engaged in order to make any activities happen as well as the human elements that will be impacted by the activities (i.e., they represent where the measures of effectiveness would be assessed).

Figure 2. A Conceptual View of the Systems that can Impact Community Resiliency.

The relationship between food and community resilience is far more complicated than the simplistic representation shown in Figure 2. The full cyclic relationship involves food production, financing, distribution, and research and development in addition to ensuring that the products are affordable, nutritious, and obtainable to those who want and need it. For the purposes of this paper we will refer to this full relationship as the "food-community resilience cycle".

In the developed world, where regional food supply may be sufficient, some urban areas experience "food deserts," as previously noted. These "deserts" can force residents to either travel long distances to find sufficient food or to settle for more abundant, but less nutritious food, from "convenience" stores and/or cheap fast food – thereby exacerbating the problem of childhood obesity and early onset of diabetes that is facing many cities in the United States.

In the developing world, these issues can be exacerbated by fundamental failures to produce and mobilize sufficient food for regional populations due to explosive growth as well as environmental issues or conflict. These issues can result in large numbers of people being undernourished (e.g., FAO, 2014). In children, this can result in their growth and long-term potential being impacted, which can further weaken community resilience.

As has been pointed out by numerous researchers, inadequate nutrition can have significant negative impacts on communities (e.g., FAO, 2014). In the developing world, poor nutrition is an underlying contributor to higher rates of child and maternal deaths. Studies indicate that providing good nutrition during the first 1,000 days of a child's life can provide significant benefits to community resilience including increasing the educational achievement possibilities and earning potential of the individual as well as boosting the gross domestic product of the country where the child lives (e.g., FAO, 2014).

Malnutrition as defined by the FAO is "…an abnormal physiological condition caused by deficiencies, excesses or imbalances in energy and/or nutrients necessary for an active, health life" (FAO, 2014). Also, as defined by the FAO, malnutrition can be manifested as undernutrition (too little food), overnutrition (too much food), and micronutrient deficiencies (not enough "healthy" food).

4. Supporting Decision Makers to Enhance the Food-Community Resilience Cycle

Any of the systems noted in Figure 2 could potentially experience perturbations that could have an impact on the food-community resilience cycle. However, using the historical record as a guide, events associated with natural disasters - whether acute (e.g., an earthquake or extreme weather event) or chronic (e.g., an extreme drought or climate change) - or ongoing conflict have been typical events that have made significant negative impacts in the food-community resiliency cycle. The events can initially impact different parts of the food-community resilience cycle and also result in secondary impacts that can reverberate throughout the rest of the system.

As noted by the FAO (FAO, 2013), the number of food crises has been rising since the early 1980s, with between 50 and 65 food emergencies every year since 2000 from a variety of sources. The duration of the recovery aspects will ultimately impact the length of time required for the cycle to return to pre-event states. Asia and Africa are the two continents that rank first in the number of people affected by food crises – and are also the continents experiencing the greatest growth in megacities.

We shall now discuss approaches on how decision support assessments of the food and community resilience cycle can be performed for the purpose of trying to assess where problems might appear and to determine where external support (i.e., from donor countries on non-governmental organizations) might be required. We shall first present a set of metrics that can be used to assess how well countries and regions are trying to strengthen their food-community resilience cycles and then discuss additional metrics that can be used to assess how effective they are in achieving the goals. These results can be used by decision makers – both internal and external to the study area - to assess where problems might exist in the food-community resilience cycle and how corrective actions can be developed and assessed for effectiveness.

4.1 Determining if Problems Exist in the Food-Community Resilience Cycle

To support the application of resilience concepts in the food and agriculture sector, the FAO developed a strategy (FAO, 2013) that has been adapted from the Hyogo Framework for Action (HFA) (UNISDR, 2005). The HFA began in 2005 as a 10-year plan with the goal of assisting countries in reducing their risks to natural disasters and climate change[1]. The HFA involved five priorities that represented the goals for each country to achieve, with each priority broken down further into a set of core indicators. The FAO Disaster Risk Reduction for Food and Nutrition Security Framework is based on four pillars that are adapted from the five HFA priorities. Table 2 lists the priorities of the HFA and the pillars of the FAO Food and Nutrition Security Framework. In comparing the HFA and FAO frameworks, there are strong similarities between the HFA priorities and the FAO pillars which suggest that analyses from the HFA could be used as proxies for FAO responses.

Table 2. The Priorities of the Hyogo Framework for Action (HFA) and the Pillars of the FAO Food and Nutrition Security Framework.

Hyogo Framework for Action Priorities	FAO Disaster Risk Reduction for Food and Nutrition Security Framework Pillars
Priority 1 – Ensure the disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.	**Pillar 1** – Enable the environment.
Priority 2 – Identify, assess and monitor disaster risks and enhance early warning.	**Pillar 2** – Watch to safeguard.
Priority 3 – Use knowledge, innovation and education to build a culture of safety and resilience at all levels.	**Pillar 3** – Apply prevention and mitigation measures
Priority 4 – Reduce the underlying risk factors.	**Pillar 4** – Prepare to respond.
Priority 5 – Strengthen disaster preparedness for effective response at all levels.	

During the original 10-year span of the HFA[2], the signatory countries conducted self-assessments of their progress in meeting the five priorities of the HFA. The self-assessments were made using a 1 – 5 Likert rating scale in which 5 denoted substantial progress had been made and 1 very little progress had been achieved. All responses involved whole number values.

Eighty six countries in the Americas, Europe, Africa, Asia, and Oceania prepared self-assessments of their progress in meeting the HFA priorities for the 2009 – 2011 time period. The responding countries covered the full spectrum of developed countries as measured by the UN HDI program, with the majority of the countries being in the categories of “medium” to “low” human development. Seven of the countries had at least one current “megacity” within their borders while others had major, rapidly growing urban areas. Figure 3 presents the HFA self-assessments over the five HFA priorities for the countries by region. As might be expected, there was considerable variability in responses among the countries.

[1]The original meeting of delegates for the HFA occurred a couple of weeks after the devastating earthquake and tsunami in the Indian ocean.
[2]The HFA will be starting a second 15-year assessment period in 2015.

(a.) (b.) (c.)

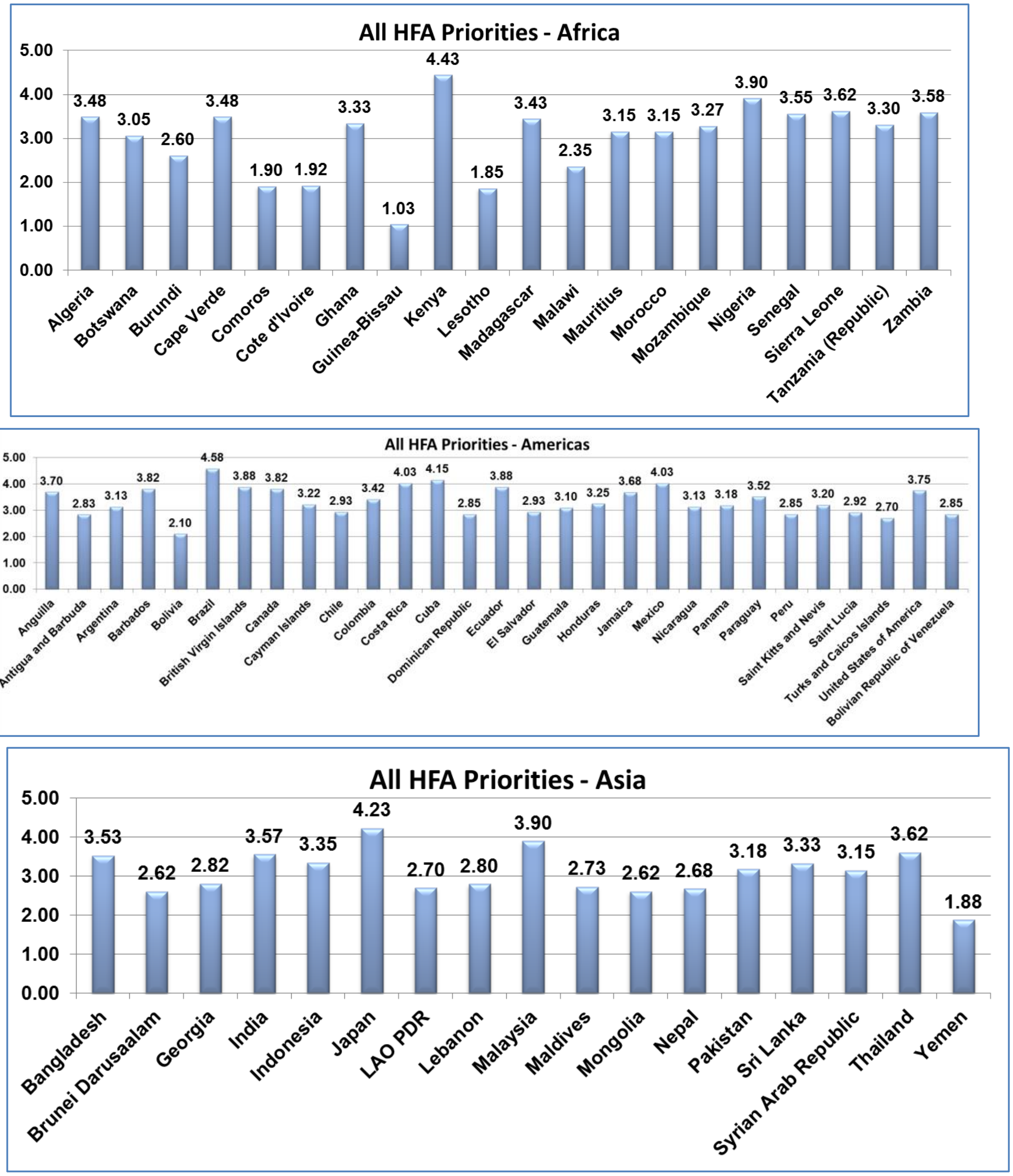
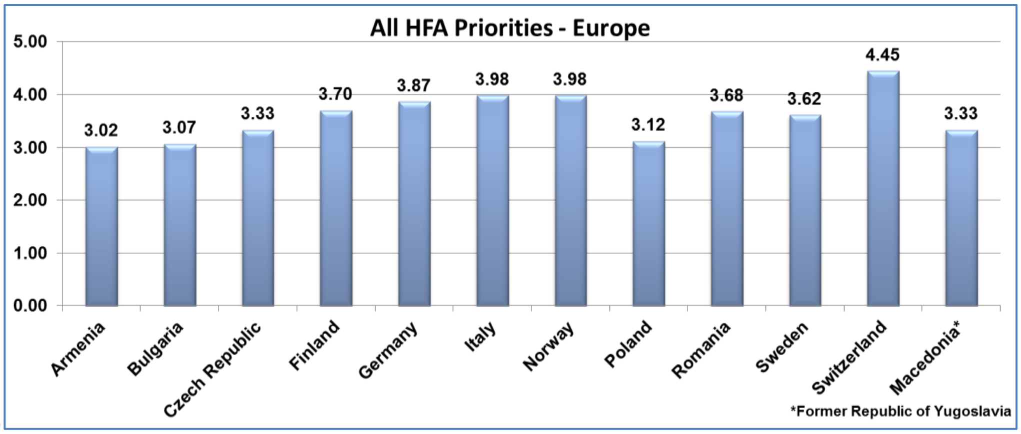
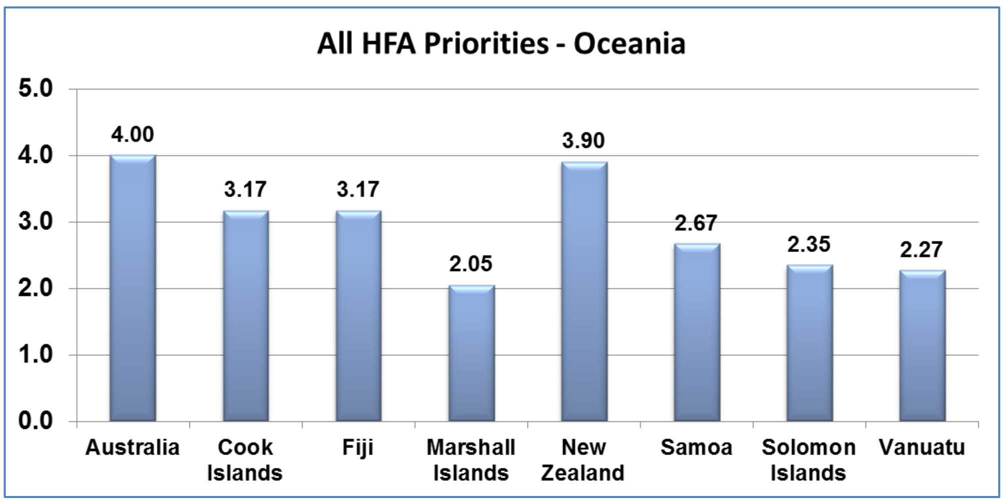


Figure 3. Average over the Five Priorities of the Hyogo Framework for Action Self-Assessments for the Reporting Countries in (a.) Africa, (b.) the Americas, and (c.) Asia.



(d.)



(e.)

Figure 3. (cont.) Average over the Five Priorities of the Hyogo Framework for Action Self-Assessments for the Reporting Countries in (d.) Europe and (e.) Oceania.

In examining the results of the HFA self-assessments, there were some expected results, such as countries that were considered to be "developing" countries according to the UN HDI efforts generally had lower reported results when compared against "developed" countries. However, there were some results that generated questions of how representative the results were. As an example, the results for Guinea-Bissau showed essentially no progress in achieving the HFA goals and the question was raised if these results were valid or if the country was just trying to attract funds from the international donor community. Seeing that the reporting format for the HFA self-assessments did not require a country to provide supporting evidence for their results, there was no way to do an independent assessment of the results. For example, the United States, which is ranked third on the UN's list of developed countries, had an average value of 3.75, which was the second lowest value in the category of "very high" human development countries. Brazil, on the other hand, which is in the category of "medium" human development, had the highest value of 4.58 for all reporting countries.[3]

Seeing that natural disasters and climate change are factors that can have significant impacts on the food-community resilience cycle, it was felt that the data from the HFA self-assessments can

[3]The date of the HFA self-assessments coincided with evaluations of bids for the upcoming summer Olympics were underway and it is speculated that Brazilian officials may have given an optimistic assessment of their progress.

be considered valid measures of what steps countries are taking to reduce potential disruptions in the food-community resilience cycle. However, because these are self-assessments they represent the perceptions of the reporting country and are probably more representative of the will of the country – the first characteristic of a resilient community. Additional metrics need to be assessed to reflect the effectiveness of the activities that are in place to support the food-community resiliency cycle.

We have performed a cross mapping of other developmental metrics against the HFA results for the reporting countries. The cross mappings were made using World Bank governance assessments (Kaufmann, et. al., 2009), data from the UN HDI efforts (UNDP, 2014), and a subset of data from the FAO food security assessments[4]. An example of one of the cross mappings is shown in Figures 4 and 5 for Guinea-Bissau, the country that reported the weakest progress in meeting the goals of the HFA priorities. Figure 4 gives the HFA self-assessment results for the five HFA priorities, the World Bank governance assessments, and a subset of the UN HDI metrics and Figure 5 presents a subset of the FAO food security metrics. Both the World Bank governance and FAO food security results are given for the 2005 to 2012 time period to mirror the time period of the HFA assessments.

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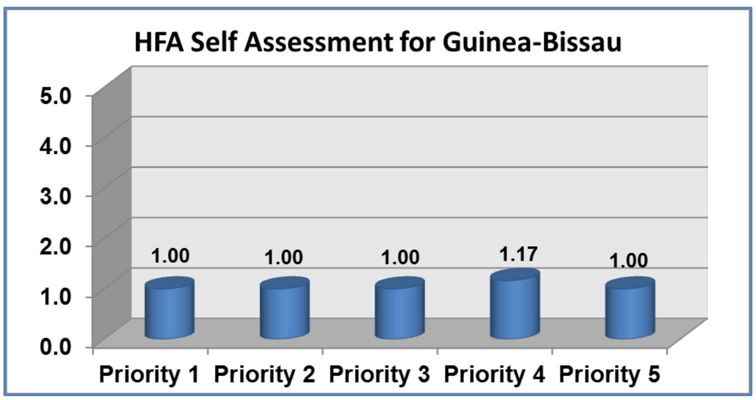

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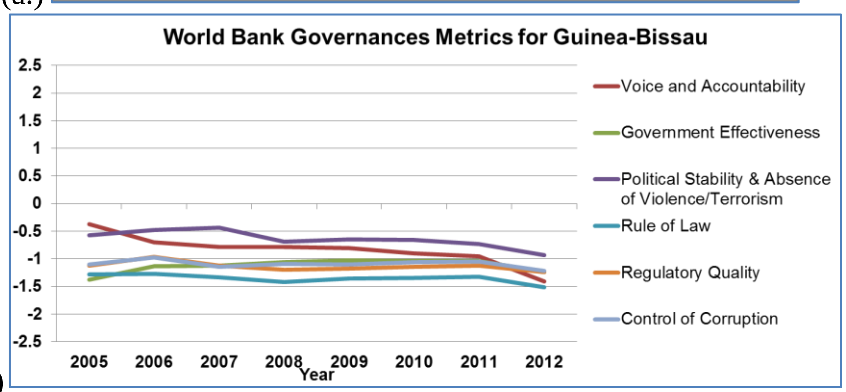


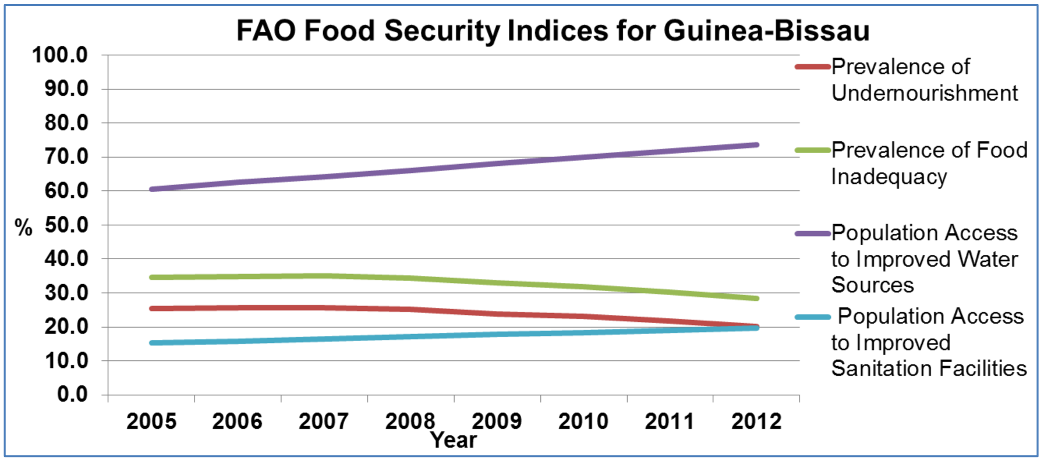
(c.)

HDI Ranking (Out of 198)	Life Expectancy at Birth (Years)	Under 5 Years Mortality Rate (per 1,000 live births)	Maternal Mortality Rate (per 1,000 live births)	Gross National Income Per Capita ($)
177 Low	54.3	129	790	1,090

Figure 4. (a.) HFA Self-Assessment Results for Guinea-Bissau (see Table 2 for the Priority definitions), (b.) World Bank Governance Metrics, and (c.) UN Human Development Metrics.

[4]http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.VVt1eE0cSUm

(a.)



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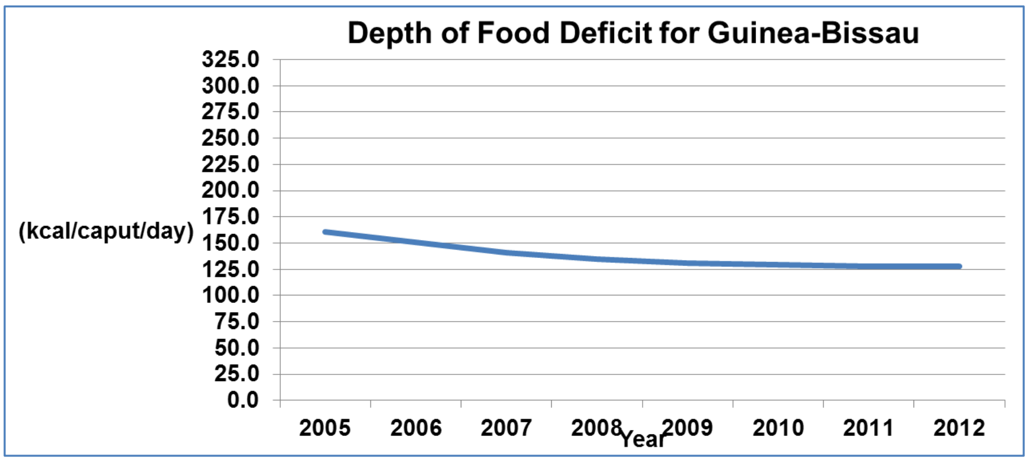

Figure 5. Comparison of a Set of FAO Food Security Metrics for Guinea-Bissau. (a.) Prevalence of Undernourishment and Food Inadequacy and Population with Access to Improved Water and Sanitation Facilities and (b.) Depth of Food Deficit, a Measure of the How Many Calories Required to Lift the Undernourished from their Status.

The World Bank assessments, which are based on a dimensionless scale of 2.5 to -2.5, assess the perceptions of effectiveness in the six noted categories by external observers. The data in Figure 4 (b.) point to significant structural problems in the governing systems in Guinea-Bissau in all of the areas assessed and support the HFA self-assessments of little to no progress being achieved.

The data in Figure 5 (a.) show the prevalence of undernourishment and food inadequacy and the percentages of the population with access to improved water and sanitation facilities. The data in Figure 5 (b.) show the "depth of food deficit," a measure of the how many calories would be required to lift the undernourished from their status. The metric is estimated as the difference between the average dietary energy requirement and the average dietary energy consumption of the undernourished population (food-deprived), is multiplied by the number of undernourished to provide an estimate of the total food deficit in the country, which is then normalized by the total population. The data presented were evaluated over a three year period centered on the dates shown.

In reviewing the ensemble of data for the 86 reporting countries, it was concluded that the HFA self-assessments are a reasonable measure of the resiliency of a country to the perturbations that can lead to disruptions in the food-community resilience cycle. Countries reporting significant progress in meeting the goals of the HFA showed high values in the World Bank governance data and a high degree of development in the UN HDI data. They also showed a low degree of food insecurity as expressed by the FAO food security metrics. Countries with little progress in meeting the HFA goals had low values in the World Bank governance data that point to significant structural problems in their governing systems. They were also on the lower end of the development spectrum as measured by the UN HDI metrics and had higher levels of food insecurity as shown in the FAO data. Finally, there were many countries that reported that they were making progress in meeting the HFA goals, but are "not there" yet. These countries were generally at moderate levels of development, had positive and improving values from the governance perspective, and were showing positive trends in addressing the food security issues. However, these countries would most likely require assistance from external sources, such as from donor countries or non-governmental organizations. In the following sections, we will discuss how analytical approaches can be used to determine where problems might exist in the food-community resilience cycle and how plans to correct them can be developed.

4.2 Determining and Correcting the Problems in the Food-Community Resilience Cycle

Utilizing the assessments discussed in the previous section, one could then delve into the details of where any problems might exist and what the causes might be. Then, assessments can be made on corrective actions to take.

The casual-loop diagramming approach, commonly used in Systems Dynamics (Sterman, 2000; Martinez-Moyano and Richardson, 2013), provides a useful approach to make these assessment. We will give two examples of assessments that can be made – one that examines where organizational problems required to achieve the HFA goals might exist and one that examines potential issues in the food-community resiliency cycle itself.

4.2.1 Addressing Organizational Challenges in Meeting the HFA Goals

In examining the HFA priorities and their core indicators, it is clear that a number of the systems noted in Figure 2 are required to achieve the goals of the HFA. We have decomposed the HFA priorities and core indicators into individual actions involving the high-level system elements shown in Figure 2. In order to accomplish the first HFA priority of ensuring that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation, several of the systems illustrated in Figure 2 would have to be involved to develop and implement a series of plans. Figure 6 shows an example, based on the steps involved in meeting the first HFA priority and its first core indicator, of the interactions involved in the development (orange links) and execution (blue links) of an HFA national disaster reduction plan. Using this decomposition process, one can examine all of the steps involved in the actions, look for potential obstacles, and assess alternate strategies.

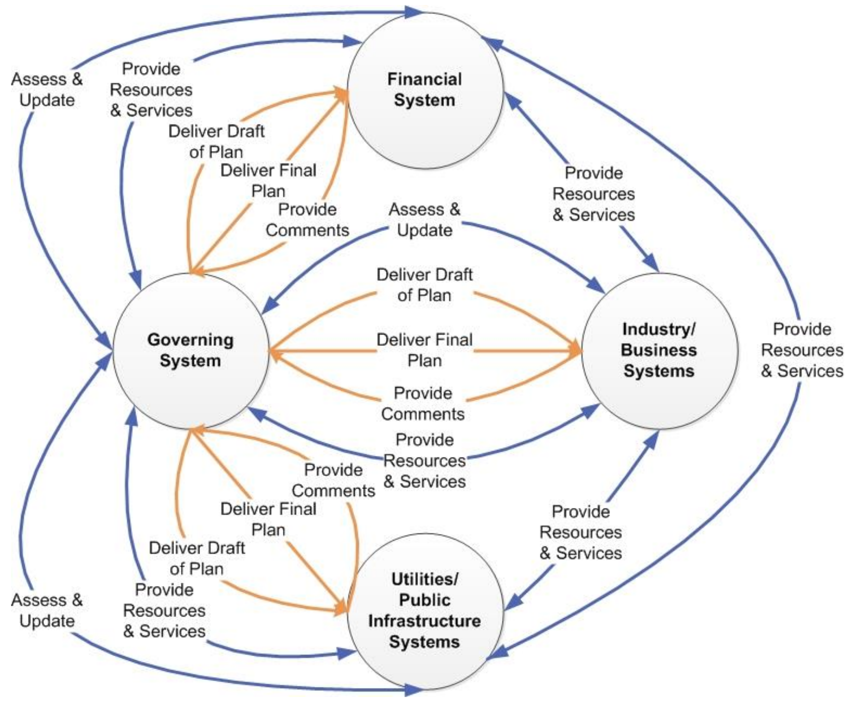

Figure 6. An Example of the Interactions Required for the Development (Orange Links) and Execution (Blue Links) of a National Framework for Risk Reduction in Response to the First HFA Priority.

4.2.2 Assessing the Food-Community Resiliency Framework

Figures 7 – 10 show a series of loops demonstrating different aspects of the food-community cycle. It should be noted that the example we will present is not comprehensive and, thus, is being used for illustrative purposes only.

As we have mentioned before, as community resiliency increases, the productivity in the community increases leading to a higher possibility to produce, improve, and distribute food. Increases in the community's ability to produce food will increase food availability that will lead to an increase in food consumption that will create the conditions for a stronger and heathier population. With a stronger population, community resiliency will further increase closing a reinforcing feedback mechanism (R1, the Food and Resiliency Loop, in Figure 7) that will lead communities to an increasingly better state over time. Additionally, as the ability of the community to improve food increases, the quality of the food will increase, further increasing food consumption leading to increases in strength and health of the population closing an additional reinforcing feedback mechanism that will make communities more resilient over time (R2, the Food Quality Loop, in Figure 7). Furthermore, as food availability increases, prices will fall increasing food affordability further fueling the possibility of food consumption creating another reinforcing mechanism of growth (R3, the Affordability Loop A, in Figure 7). The affordability loop, however, will be curtailed by a balancing mechanism—a feedback mechanism that will create a response contrary to the current flow of events in the system—created by the effect of food quality on food price. As food quality increases, food price will increase lowering food affordability (B1, the Affordability Loop B, in Figure 7). The actual affordability of the food in the community will be result of the two effects (food quality and food availability) acting on food price at the same time.

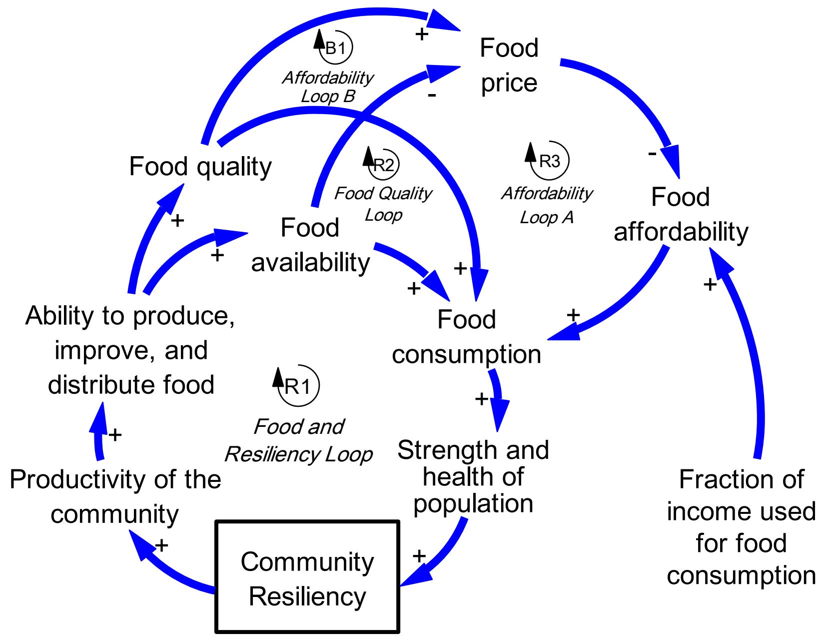

Figure 7. Food and Resiliency Loop and other Food-related Loops that Contribute to the Food-Community Resiliency Cycle.

Patterns of food consumption in a community will create a need for food production and distribution that, after some time delay, will materialize in investments in food production infrastructure. As the investments in infrastructure come online, the ability of the community to produce, improve, and distribute food increases creating another reinforcing feedback mechanism that will generate major benefits (R4a, the Food Production and Distribution Loops, in Figure 8). Additionally, the need for additional food production will change the fraction of income used for investment creating another reinforcing mechanism that will increase the amount of investment in infrastructure as the need arises (R4b, the Food Production and Distribution Loops, in Figure 8). These two reinforcing mechanisms will drive investment and production to higher levels over time creating the conditions for increases strength and health in the population and community resiliency. However, these mechanisms cannot grow indefinitely, as there are limits to the resources to invest and other constraints that prevent these from dominating the behavior of the system.

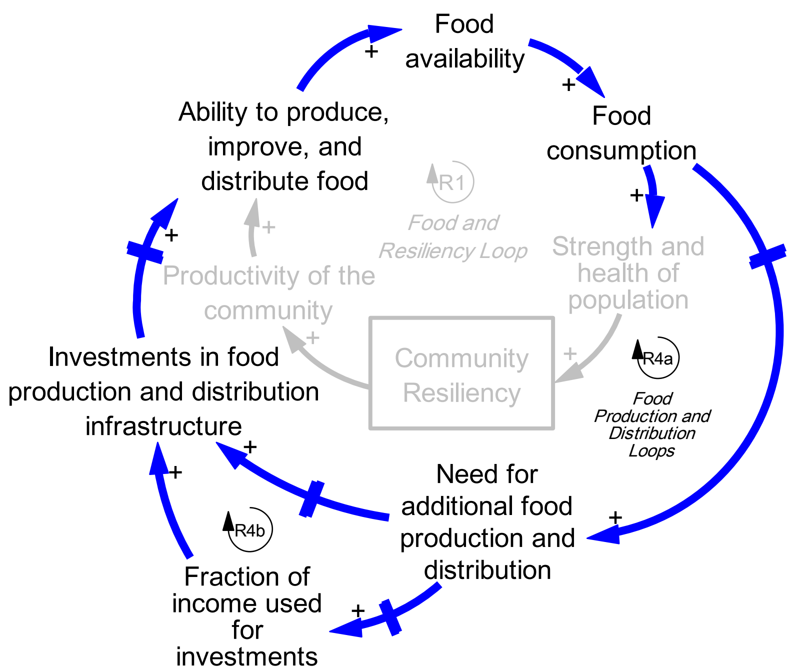

Figure 8. Food-Community Resiliency Cycle Expressed Using Casual-loop Diagramming from Systems Dynamics: Food Production and Distribution Loops.

Investments in food production, as we mentioned before, will lead to higher ability to produce, improve, and distribute food that increases food availability and food quality. Increases in food quality increases food price. Price, in turn, creates revenue that turns into incentives to invest, after some time delay, further increases investments creating another reinforcing cycle of growth (R5, the Food Production Incentive Loop, in Figure 9). However, as described before, higher ability to produce, improve, and distribute food also increases food availability that decreases price. Lower prices will lead to deceases in incentives closing a balancing mechanism of production (B3, the Food Production Incentive Loop, in Figure 9) that will counter the potential growth of R5. Both mechanisms are active at any given point in time and compete for control of price behavior and its consequences in terms of food quality, availability, consumption, strength of the population, community resiliency, etc.

Additionally, the fraction of income used for investments determines the fraction that is available for consumption. As the fraction of income used for investments increases, the fraction available for consumption decreases making food affordability suffer leading to lower levels of food consumption. This process closes a balancing feedback mechanism (B2, the Income Use Substitution Loop, in Figure 9) with the potential to create important damage to the community as it may trigger low "perceived" levels of need for production given low levels of consumption even when low consumption is a function of low food affordability and not actual need. This process, also, can create a situation of chronic underinvestment in communities with not enough resources to be able to both satisfy the investment and consumption needs. An important problem in communities that deals with how to balance short-term pressures with long-term needs.

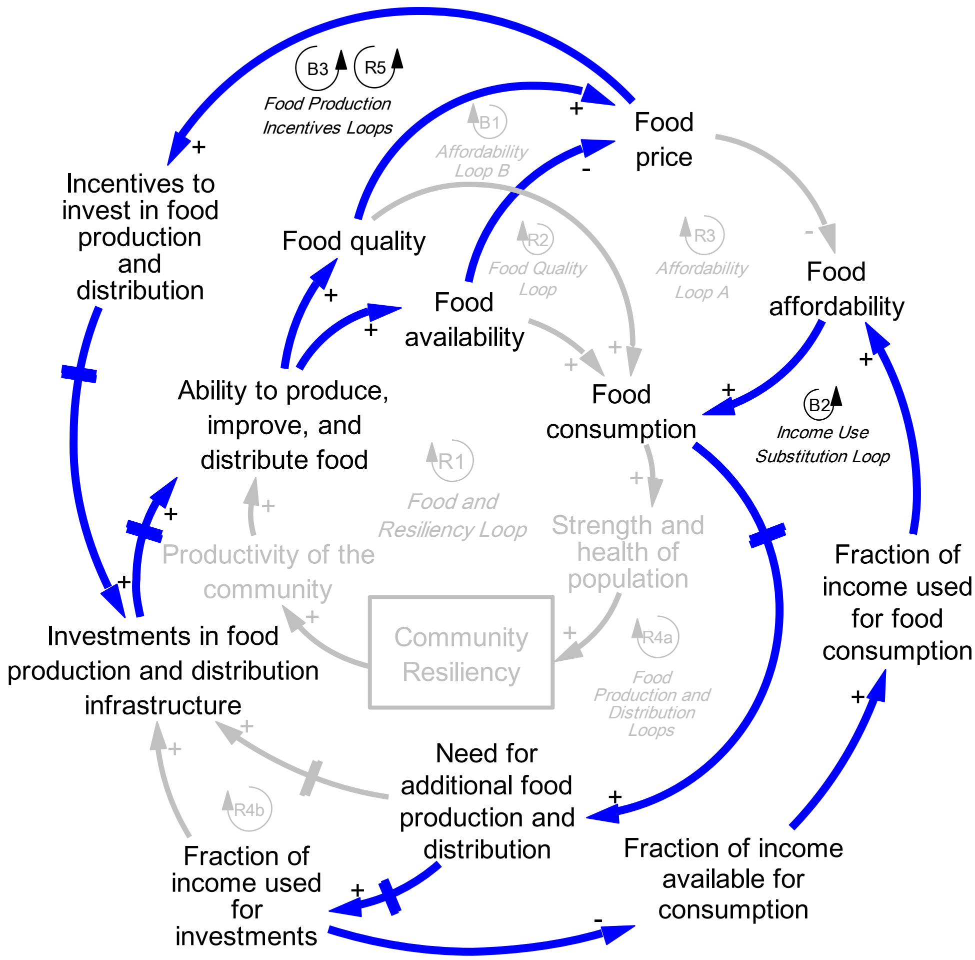

Figure 9. Food-Community Resiliency Cycle Expressed Using Casual-loop Diagramming from Systems Dynamics: Food Production and Distribution Loops.

Once an assessment of the state of an existing food-community resilient cycle has been made of a region), we posit that simulation-aided decision support system tools could be used that would enable stakeholders to make informed decisions in areas of the world under stress - most notably for (a) evaluating and tracking societal stability and resiliency at multiple spatial and temporal scales, and (b) helping to ensure effective delivery of food and other essential services, in the full context of concurrent social, economic, and environmental processes and infrastructure performance. Further, these analyses could also support the development of Analytical Hierarchical Processing (AHP) based capability assessments that allow communities to assess potential outputs based on the chose option. Since food is a commodity that can be supplied in a myriad of ways, such systematic analysis allows consideration and comparison of different remedies to the problem.

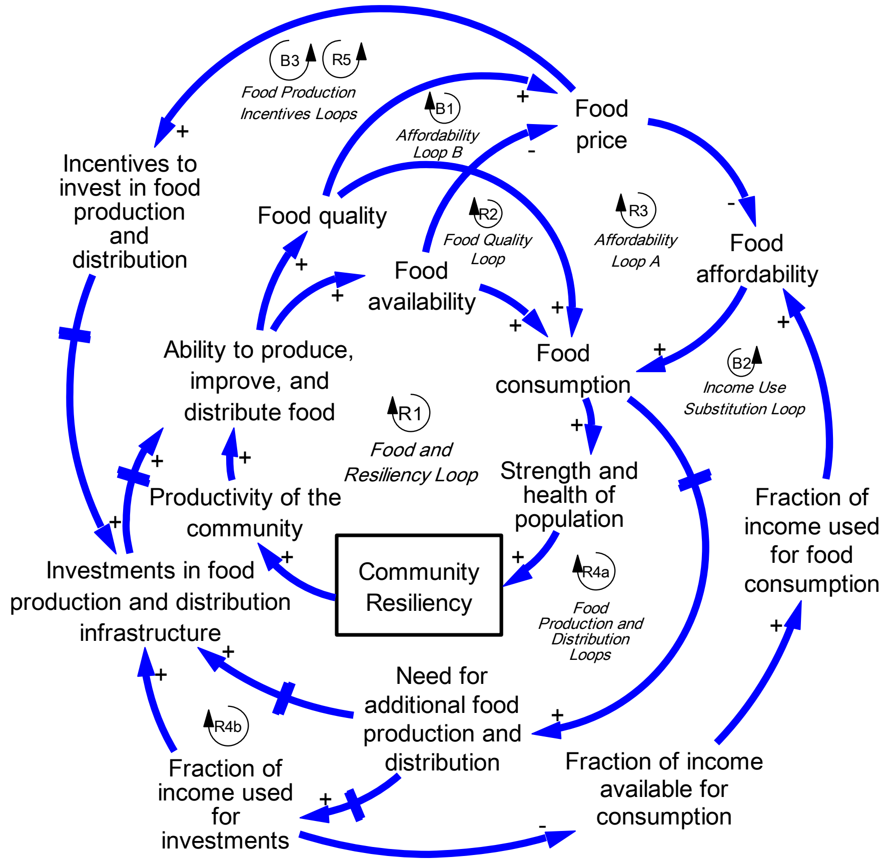

Figure 10. A Notional Example of the Food-Community Resiliency Cycle Expressed Using Casual-loop Diagramming from Systems Dynamics.

Once an assessment of the state of an existing food-community resilient cycle has been made in an area being studied, we posit that simulation-aided decision support system tools could be used that would enable stakeholders to make informed decisions in areas of the world under stress - most notably for (a) evaluating and tracking societal stability and resiliency at multiple spatial and temporal scales, and (b) helping to ensure effective delivery of food and other essential services, in the full context of concurrent social, economic, and environmental processes and infrastructure performance. Further, these analyses could also support the development of Analytic Hierarchic Process (AHP) modeling based capability assessments that allow communities to assess potential outputs based on the chosen option. Since food is a commodity that can be supplied in a myriad of ways, such systematic analysis allows consideration and comparison of different remedies to the problem (Schneider, et al, 2015).

4.2.3 Developing Modeling and Simulation Support Tools

Ultimately, the goal is to develop a robust and sustainable food-community resilience system. Seeing that the outcomes of these systems cannot be immediately assessed, advanced modeling and simulation tools may be required to do various "what if" studies on the effectiveness of changes made in the food-community resilience cycle. In this paper we will not present a review of the types of modeling and simulation tools that are available, but instead will address the larger conceptual issues involved when employing these resources.

The first issue is that analyses of the food-community resilience cycle can only be accomplished from a system-of-systems perspective. As discussed earlier in the paper, the cycle is more than just about generating food. There are multiple interactions and dependencies between the elements in a resilient community system that must be identified and represented.

A second major issue is that the interactions and processes that are required to model the complete system can operate at widely varying spatial and temporal scales. This is demonstrated in Figure 11 which is based on work done at Argonne (Christiansen and Altaweel, 2006; and Wilkinson, et.al, 2007) to model the impacts of environmental factors on simulated communities. The models have been used to support studies on infrastructure and environmental linkages in rural villages in Thailand, Iraq, and Afghanistan. The top timeline in Figure 11 highlights the temporal scales associated with the various processes. The spatial scales of the different processes are equally variable and can range to micro scales (e.g. cloud microphysics and plant dynamics), to macro scales (e.g. state administration and climate dynamics). Effectiveness can be difficult to measure because the impacts of changes in the modeled processes can be distant from the time and place of the occurrence. For example, the impacts of improvements in childhood nutrition will most likely not be felt at the societal level until the children become contributing members of the society. Likewise, the locations where the children become contributors can be very distant from their food source.

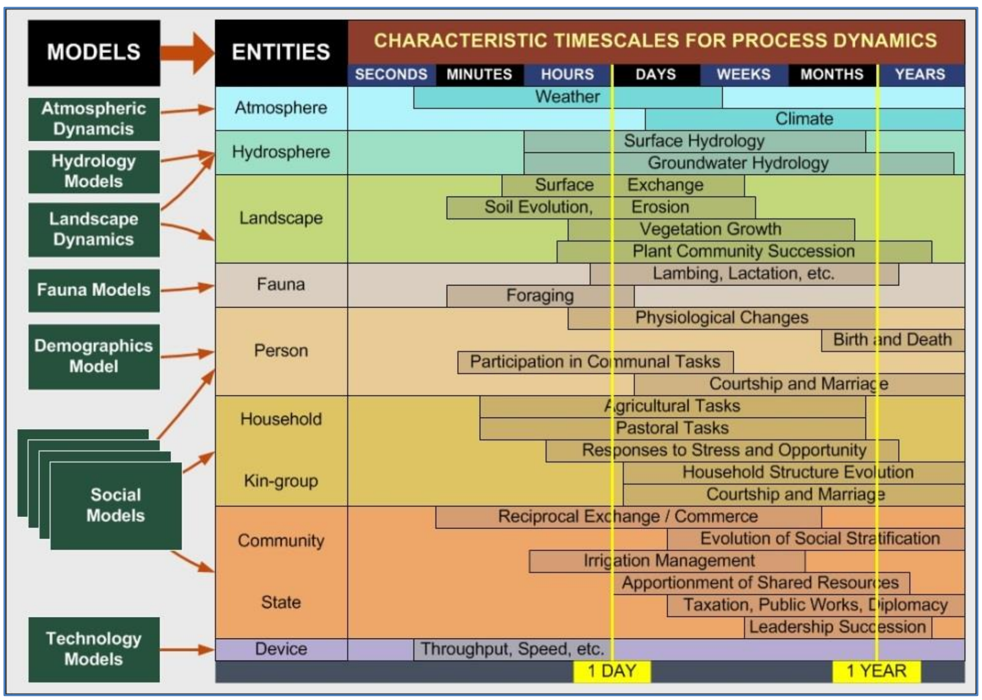

Figure 11. An Example of the Variability in Temporal and Spatial Scales of Different Physical and Social Processes. (Christiansen and Altaweel, 2006; and Wilkinson, et.al, 2007)

5. Summary and Way Forward Recommendations

A smoothly running food cycle is a foundational system within a functional society and a key contributor to community resilience. If this process is not sufficient the community cannot fully contribute to the world around them, and rather than becoming an asset, those in food insufficiency become a liability, and the problem is magnified.

In this paper we have discussed the relationships in the food-community resilience cycle. We have presented various analytical methods that can be used to assess the efficacy of existing food-community cycles in urban and regional areas in order to identify where potential problems may exist. Finally, we have also discussed how simulation-based decision support tools can be used to provide decision makers with approaches that can enhance the food-community resilience cycles. We feel that these approaches can provide valuable contributions to the FAO in support of their Meeting Urban Food Needs program.

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Bibliography

Christiansen, J.H. & Altaweel, M. 2006, Understanding Ancient Societies: A New Approach Using Agent-Based Holistic Modeling. Structure and Dynamics: eJournal of Anthropological and Related Sciences, Vol. 1: No. 2, Article 7. http://repositories.cdlib.org/imbs/socdyn/sdeas/vol1/iss2/art7/

FAO. 2013, Resilient Livelihoods – Disaster Risk Reduction for Food and Nutrition Security Framework Programme, 2013 Edition, Rome, Italy, April. http://www.fao.org/docrep/015/i2540e/i2540e00.pdf

FAO. 2014, Strengthening the Links Between Resilience and Nutrition in Food and Agriculture, A Discussion Paper, Food and Agriculture Organization of the United Nations, Rome, Italy.
http://www.fao.org/3/a-i3777e.pdf

Hummel, J. 2014, Final Report for the Workshop on Analytical Support for Societal and Regional Resiliency in Support of National Security, Argonne National Laboratory, Argonne, IL, ANL/DIS-14/4.

Kaufmann, D., A. Kraay, A. & Mastruzzi, M. 2009, Governance Matters VIII, Aggregate and Individual Governance Indicators, 1996-2008, Policy Research Working Paper 4978, The World Bank, Development Research Group, Macroeconomics and Growth Team, June.
http://econ.worldbank.org/external/default/main?pagePK=64165259&theSitePK=469372&piPK=64165421&menuPK=64166093&entityID=000158349_20090629095443

Martinez-Moyano IJ, Richardson GP. 2013. Best practices in system dynamics modeling. System Dynamics Review 29(2): 102-123.

J. Schneider, C. J. Romanowski, R. K. Raj, S. Mishra and K. Stein, "Measurement of locality specific resilience: an operational model," 2015 IEEE International Conference on Technologies for Homeland Security (IEEE HST 2015), Waltham, MA. April 2015.

Sterman JD. 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. Irwin McGraw-Hill: Boston, MA.

UNDP. 2014, Human Development Report 2014 - Sustaining Human Progress: Reduction Vulnerabilities and Building Resilience, United Nations Development Programme. http://hdr.undp.org/sites/default/files/hdr14-summary-en.pdf

UNISDR. 2005, Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters, Geneva, Switzerland, United Nations International Strategy for Disaster Reduction. http://www.unisdr.org/2005/wcdr/integover/official-doc/L-docs/Hyogo-framework-for-action-english.pdf

United Nations. 2014, World's Population Increasingly Urban with More Than Half Living in Urban Areas, 10 July, http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html

Wilkinson, T.J., Christiansen, J.H, Ur, J., Widell, M. & Altaweel, M. 2007. Urbanization Within a Dynamic Environment: Modeling Bronze Age Communities in Upper Mesopotamia. American Anthropologist Vol. 109, No. 1, 52-68.