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From complexity to food security decision-support: Novel methods of assessment and their role in enhancing the timeliness and relevance of food and nutrition security information

Nancy Mock*, Nathan Morrow, Adam Papendieck

Tulane University, Disaster Resilience Leadership Academy and Department of Global Health Systems, 6056 Prytania St., New Orleans, LA 70118, United States

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ABSTRACT

Food and Nutrition Security Information (FNSI) is a critical tool for achieving food and nutrition security, yet FNSI efforts to date have not produced the intended impacts on policy and program decision making, largely due to shortcomings in available technologies and frameworks. The article reviews the evolution of FNSI efforts in the context of emerging technology and data collection techniques. A conceptual framework is provided to describe the evolution towards an FNSI characterized by integrating conventional and novel approaches to the collection, analysis and communication of information into a value stream that supports decision-making to achieve food security. Conclusions include the need to streamline and expand coverage of conventional information tools such as household surveys while facilitating the rapid uptake of analytical tools that leverage the novel, numerous, and rich data streams enabled by emergent information and communication technologies and dramatic increases in connectivity.

1. Introduction

Food security and nutrition problems affect people worldwide. The FAO recently estimated that 870 million people are undernourished while other authors suggest that as many as 2 billion people may suffer micronutrient deficiencies (FAO, 2012; Klotz et al., 2008; Bloem et al., 2009; Mason, 2001; Knight, 2011; UNSCN, 2010b; Horton, 2009). Considerable differences in the estimate of food and nutrition insecure people are largely due to the lack of comparable global level datasets containing consistent, regular, and synoptic measurement of key food security indicators. This issue is compounded by estimation methods that involve making broad assumptions (Barrett, 2010; FAO, 2012). The determinants of food and nutrition security have become increasingly globalized as reflected by recent food price volatility beginning in 2007 and 2008 (IFPRI, 2011; Webb, 2010). In a world that is both increasingly urban and increasingly interconnected, many families are relying on the market for a larger and larger share of their food (Ruel et al., 2009; Aslam et al., 2012). During the recent food price crisis, seemingly unrelated weather events, policy changes and market feedback sent prices spiraling upward and put basic food out of reach of millions of families, highlighting the complexity involved in achieving food and nutrition security (FNS) (Ghanem, 2008; Zezza, 2008; Headey and Fan, 2008; Sulaiman et al., 2009).

An important requirement for achieving food and nutrition security is timely, reliable and relevant information (FAO/WFP, 2011; Fan, 2012). Since the 1970s, substantial resources have been devoted to developing approaches and techniques which provide Food and Nutrition Security Information (FNSI) in support of improved decision-making related to food and nutrition security outcomes (Hawkes, 1974; UN, 1975; Buchanan-Smith et al., 1991). FNSI has been applied to specific decision-making problems such as early warning and emergency response planning, analyzing the need for market oriented interventions, and development policy formulation and evaluation. Indeed, organizations concerned with global food and nutrition security have invested in information systems that have aimed to develop on-going information collection, analysis and communication around both acute and chronic food and nutrition security problems. These include such efforts as the United States Government-sponsored Famine Early Warning Systems Network (FEWSNET), the UN Inter-agency Food Insecurity and Vulnerability Information and Mapping Systems Initiative (FIVIMS), the UN Food and Agricultural Organization's Global Information Early Warning System (GIEWS) among others. FNSI efforts traditionally have synthesized information from sources such as routine statistical data collection, synoptic monitoring from satellite remote sensing, and large cross-sectional surveys (Ecker and Breisinger, 2012; Brown, 2008; Devereux et al., 2004). Simple conceptual frameworks illustrating cause and effect relationships between

* Corresponding author.
E-mail address: mock@tulane.edu (N. Mock).

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health, nutrition, economic access and production have been used to organize data (FAO, 2011; Pinstrup-Andersen, 2009; Barrett, 1999; UNICEF, 1990). FNSI efforts aim to inform regular decision-making processes that prioritize food aid, market intervention and development-oriented policies.

Recent research, however, suggests that normative approaches to FNSI have been only partially successful in providing decision support (Barrett, 2010). These efforts have been hampered by a number of issues related to the lack of valid and reliable data, inadequate processing and analysis of data and the timeliness of information. Evaluations of FNSI efforts repeatedly find that they often do not deliver what decision makers need (Knight, 2011; WFP/FAO, 2009; EC/FAO, 2009; Benson et al., 2008; FAO, 2012). Furthermore, the functional and often physical separation of those that collect data from those that analyze the data and in turn from the intended users of FNSI tends to contribute to a disconnect between information and action as witnessed during the response to the famines in the Horn of Africa (Buchanan and Davies, 1995; Devereux, 2001; Funk, 2011; Hillier and Dempsey, 2012). Particularly at the national level, the communication of FNSI among different stakeholder groups and between individual knowledge producing activities and the broader collection of decision-makers and information-users is a traditional challenge resulting in poor linkages between information and decision-making (Devereux, 2001). Advances in Information/Communications Technologies (ICTs), however, have resulted in an explosion of new data streams and transformational tools for assessment of FNSI.

The article briefly reviews the evolution of FNSI initiatives from a complex systems perspective, analyzes the utility of recent technological advances and provides examples of how novel methods of assessment can strengthen FNSI efforts. For the purposes of this article, "assessment methods" refer to methods for information capture, curation, analysis and communication of FNSI.

1.1. Theories and frameworks useful to understanding modern decision support

Key to improving FNSI is to understand related initiatives as decision support for improved FNS. The recent Panel on Strategies and Methods for Climate-Related Decision Support studied the science of decision support and its evolution in modern times as it applies to the problem of climate change. They defined decision support broadly as "a set of processes intended to create conditions for production of decision relevant information and for its appropriate use" and argue that decision support systems are comprised "of the individuals, organizations, communications networks and supporting institutional structures that provide and use decision support products and services" (National Research Council, 2009). The panel concluded that the decision support enterprise has evolved considerably in recent years, in part facilitated by theoretical shifts in thinking about complex problems such as food security, climate change and sustainability, and in part because technological advances enable more sophisticated methods of data capture, management, analysis and connectivity to end-users.

While earlier efforts emphasized data and data systems designed by analysts, modern notions of decision support also emphasize information networks, close connectivity between providers and users of information and adaptive change (see text Box 1).

Box 1–A recent National Academy of Sciences study identified six Principals of Decision Support:

1. Begin with users' needs: these needs are not always known in advance, and they should be identified collaboratively and iteratively in ongoing two-way communication between knowledge producers and decision makers.
2. Give priority to processes over products: to identify, produce, and provide the appropriate kind of decision support, processes of interaction among and between decision support providers and users are essential.
3. Link information producers and users.
4. Build connections across disciplines and organizations: decision support services and products must account for the multidisciplinary character of the needed information.
5. Seek institutional stability: stable decision support systems are able to obtain greater visibility, stature, longevity, and effectiveness.
6. Design for learning: decision support systems should be structured for flexibility, adaptability, and learning from experience.

Source: National Research Council (2009).

1.2. Complex adaptive systems and the FNSI value stream

These modern conceptions of decision support are rooted in an interpretation of complex problems like food and nutrition security as complex systems problems (Jones, 2011) where many interrelated networks of individuals, households, communities, and organizations are connected in intricate ways. These intricate networks face risks and threats such as climate change, environmental degradation, war, energy policies and water use practices, among others. For example, drought affecting one major global cereal producer such as Russia or Australia combined with energy policies in the United States could have dramatic effects on global cereal prices, eroding dangerously the terms of trade for vulnerable households around the world (Abbott et al., 2008). Added to this increasing interdependence is the importance of understanding local context. Policies in some vulnerable countries regarding the acceptability of food derived from Genetically Modified Organisms (GMOs) have at times prevented food aid relief (Zerbe, 2004). The specific local causes of nutritional stunting vary widely according to local determinants of nutrition security. Complex systems thinking highlights the need for highly contextualized analysis that takes such local, interdependent determinants into account throughout the broader system. Such an analysis is contingent upon establishing FNSI of requisite complexity and adaptability.

Complex Adaptive Systems (CAS) represents a desired state where a system's complexity (and all its components) is modulated by timely and appropriate adaptation of the system based upon rapid learning (Holland, 1995). CAS depends upon rapid and efficient information feedback loops across the network of components. Information flow reflects multi-directional connectivity, in contrast to the one way flow of information that characterizes many conventional information systems. Benbya and McKelvey (2006) describe how information systems may achieve a high level of complexity through a process of "co-evolutionary development" within the context of a CAS. In such a competitive/adaptive environment, "official" systems designed from the top–down by institutional information specialists often interact with "emergent" initiatives which tend to be designed in response to information gaps, inefficiencies and other concerns as perceived by a much broader set of stakeholders, end-users and sometimes even the immediate beneficiaries of the system. Such emergent systems and tools are often—but not always—developed in a modular and distinctly bottom–up fashion. To the extent that a system for the provision of FNSI exists, it is useful to understand it as a set of co-evolving components, some of which are conventional and some of which are emergent.

For example, historically FNSI has been mandated by international declarations (e.g. GIEWS, FIVIMS, and MICS) or was developed as an instrument to inform donor country policy (e.g. FEWS). Information from these systems informs a relatively small number of decisions at high levels of policy but requires considerable ongoing data collection effort. On the other hand, a myriad of approaches to gathering FNSI at the local level proliferate from volunteer and civil society organizations to meet their immediate operational, targeting, and monitoring information needs (Maxwell et al., 1999). These in turn help these organizations develop evidence-based advocacy campaigns to influence policy or resource allocation. In this way, novel approaches for gathering FNSI developed by a broader set of stakeholders may add value to conventional FNSI, if not replace or compete with it.

Critical to the co-evolutionary development of FNSI are the rapid information feedback loops which decrease the amount of time it takes for developers and end-users of FNSI to assess changes in performance associated with novel assessment techniques or new FNSI. One way to assess performance is to borrow from quality management literature the concept of the value stream (Krafcik, 1988) and identify component impact on the set of steps linking information production to use for decision support. The value stream here is the set of activities from data capture, curation (selection, documentation, management and storage), analysis, communication and use. In using this framework (Fig. 1), great importance is placed upon the use of information. Users are the drivers of the value stream and of continuous quality improvement of FNSI. Maintenance of customer (user) focus and reduction of inefficiencies are key principles for improving the decision support value chain.

While conventional normative FNSI to date have focused resources and time on the data collection component of the value stream, emergent methods tend to leverage new ICTs for more efficient assessment and allow resources to be focused on data use. Emergent approaches to assessment enable data to flow much more rapidly through the value stream. Resources are likewise focused on data visualization, analytics, contextualization and end-user defined information products. Conventional analysis of FNSI tends to be analysis-driven and oriented primarily to a pre-defined purpose (i.e. The Millennium Development Goals). The "communication" step in the value stream is conventionally limited to simple "dissemination", enabling little opportunity for feedback or use by the broader set of stakeholders such as those at the community-level. Emergent FNSI places much greater ownership of FSNI in the individual and community-levels, stressing communication feedback loops to fine tune analysis for different user-groups.

2. Evolution of FNSI decision support initiatives

FNSI initiatives always have been facilitated by technological advances and by an ever improving understanding of the determinants of FNS. The emergence of FNSI as decision support in modern times can be traced back to the co-evolution of food and nutrition security information efforts when in the 1970s global attention was turned to declining food stocks and rising food prices coupled with the drought-precipitated famine in the Sahel and post-independence famine related to flooding in Bangladesh. Delegates to the 1974 World Food Conference in Rome agreed to share agricultural production estimates in advance of shortfalls with the Food and Agriculture Organization of the United Nations as part of a global early warning system (FAO, 1985). "Participating in and supporting the operation of the Global Information and Early Warning System on Food and Agriculture" (GIEWS) was the first commitment to the establishment of an effective information system for world food security adopted by the conference in the Universal Declaration on the Eradication of Hunger and Malnutrition (FAO, 1975). The interagency Standing Committee on Nutrition (SCN) was a parallel initiative launched at nearly the same time and focusing specifically on nutrition surveillance (WHO, 1976; Mason et al., 1984). At this time, basic uses of food and nutrition information/surveillance were defined related to early warning, policy formulation and program management. While the GIEWS

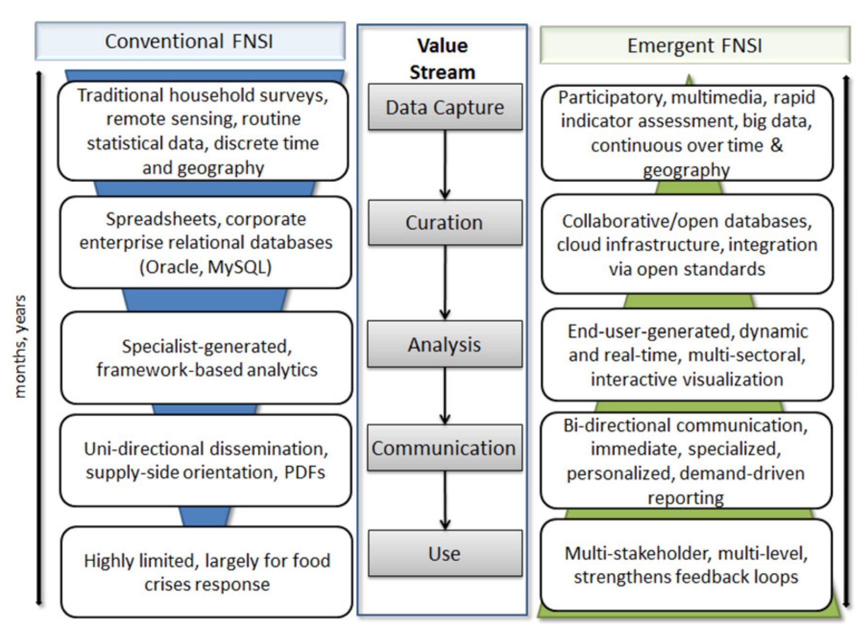

Fig. 1. FNSI Value Stream. The figure highlights characteristic methods and technologies employed at the various stages of the value stream from information production to use. Making use of recent ICT and enhanced connectivity, emergent FNSI assessment methods tend to move information through the value stream much more rapidly. The colored triangles are intended to highlight how the effort/resources expended throughout the value stream tend to be shifted towards information use and away from data collection for emergent methods as compared with traditional. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

system resulted in annual assessments of national level cereal balances (Newhouse, 1987), nutrition surveillance emphasized the measurement and monitoring of proxies of nutritional status—primarily anthropometric measures—though this early effort also gave rise to a number of FNSI efforts to analyze causes and nutritional results of interventions aimed at improving nutrition. These early efforts were initiated and operated by specialized analytical units within the UN, the United States Centers for Disease Control, and academia. They gave rise to information systems schematics and definitions of food security and nutrition surveillance.

An early example of systems adaptation to meet FNSI demands, technological advances in the use of satellite imagery enabled global monitoring of production failure at the sub-national levels for the first time beginning in the 1980s. Satellites originally built to monitor weather also recorded seasonal green up of pasturelands and rain fed farming areas of semi-arid tropics that could be used to estimate the start and length of the growing season as well as measure relative declines in vegetation growth as a sign of drought (Tucker, 1979; Tucker and Choudhury, 1987). Following the 1984 famine in Northern Ethiopia, the United States Agency for International Development initiated its own Famine Early Warning System project (FEWS) and satellite imagery became the cornerstone for monitoring efforts by providing decision-makers with an "impartial and authoritative" source for information in remote areas where rainfall and other indicators were scarce (Willis, 1985). The GIEWS in Rome also received decadal updates derived from US satellite data and later developed their own system for processing satellite imagery called Advanced Real-Time Environmental Monitoring Information System, ARTEMIS, that went on to incorporate information from a number of different countries' satellite platforms (Hutchinson, 1991). Even today when production failure is widely acknowledged as having relatively little to do with the socio-economic conditions at the root of famine conditions, images derived from satellite remote sensing remain a primary product of many early warning systems because they offer a synoptic and comparatively inexpensive global source of early warning information that maintain an appearance of objectivity (Brown, 2008). This stage of evolution produced more emphasis on the types of information products that would be useful to high level decision makers in international organizations, concerned with food aid management in emergency and non-emergency contexts.

At the same time, in both the food security and nutrition information communities, an increased awareness of the role of socio-economic determinants of food and nutrition insecurity and famine emerged. Drèze and Sen (1989, 1990) and Sen (1981a, 1981b) used the theory of entitlements to explain failures in household access to food as a significant cause of famine and chronic food and nutrition insecurity. Price and wage data were essential to the analysis of household level access to food and how changes in access affected household food security. This period saw the emergence of large scale household surveys as important to FNSI efforts. But at that time, survey planning, execution, analysis and dissemination was time consuming, expensive and reliant on a very small number of experienced researcher/analysts (McCalla and Mock, 2004). During this same time, information on household access to food was informed by the market information systems that proliferated in the 1980s and 1990s. With agricultural liberalization, consumers and producers were exposed to greater food security risk from seasonal price volatility and other market risks such as speculation, fuel prices, and poor market integration (Devereux, 2001). Prices proved useful to monitor sharp decreases in supply and proxies were developed to monitor relative changes in entitlements for different livelihood groups, such as pastoral and subsistence agricultural communities.

There was little integration of the food security and nutrition surveillance/information systems community efforts. Users of FNSI were limited to a small group of analysts and higher level program and policy makers.

The 1990s also witnessed the evolution of explanatory frameworks for FNS. FNSI systems were developed to collect data and assess food and nutrition security status in terms of availability, access, utilization and stability. This broader scope of food security led to greater efforts to collect more indicators in more places. The UNICEF Multiple Indicator Survey program (MICS); the USAID-sponsored Demographic and Health Surveys (DHS); The World Bank Living Standard Measurement Survey (LSMS); and the World Food Program's Vulnerability Analysis Mapping (WFP/VAM) program all generated extensive household-level data that was incorporated with complementary information to characterize FNS in varying contexts.

These large-scale data collection efforts produced estimates for many indicators at national and sometimes secondary administrative units. Data collection and analysis for these surveys was time and resource intensive. Results of these surveys largely served to inform high-level policy discussion and were only repeated in multi-year cycles. Again, effort and resources were focused on the top of the FNSI value chain, primarily on data capture.

In response to more operational and programmatic information requirements, organizations concerned with FNS at more local scales developed a plethora of approaches and methods for more regular and context specific FNSI. Beginning in the late 1990s, livelihoods approaches had become dominant in assessing and monitoring the multi-dimensionality of poverty at the household and community level, including access aspects of food security (Alwang et al., 2001; Boudreau, 1998). Adapting qualitative approaches from social science research, local and international organizations now regularly collect and analyze information on access to food and proxy indicators for utilization. Several non-governmental organizations also have adapted DHS questionnaires and measure anthropometry in their service areas. Other approaches and indicators of food security have been developed specifically to serve operational decision-making, such as coping indexes that assess the severity of food insecurity through measuring household behavioral change in response to food shortages (Davies, 1993).

Most recently, probability household survey approaches are being used to capture information on more specific measures, for example, nutrition and mortality in crisis contexts (SMART, 2006) and to collect small area statistics using rapid probability methods as illustrated by World Vision International's Transformational Development Indicators initiative and the successor Child Well-Being Outcome Measurement initiative.[1] Even traditional large scale survey programs are increasingly collecting data that can be disaggregated to third order and lower administrative levels. This development has broadened the user base of FNSI to include more decision makers within Non-governmental Organizations and local organizations.

More emphasis has also been placed on developing analytical frameworks to integrate data from disparate sources and to digest this into more decision-relevant formats. An example is the Integrated Food Security Phase Classification (IPC) where analytic outputs from various data collection activities are integrated and mapped to summarize food security status (IPC Global Partners, 2008). Likewise there has been more prominent integration of micro- and meso-level assessments at the district and small area

[1] World Vision International in their Transformational Development Indicator surveys collected more than 9.5 million individual anthropometric measurements in more than 80 countries and more than 1000 individual project sites.

levels in an attempt to make FNSI more relevant to decision-makers. Still, however, the stakeholder base largely rests with UN organizations and international NGO users.

Throughout 35 years of FNSI development, constant adaptation to new demands and greater understanding of FNS is the norm rather than the exception. New technology and emergent groups have played a role in shaping the sources of information and approaches to producing FNSI. Recent ICT advances are generating a wide array of possibilities to improve the FNSI value stream. Some of the resulting novel methods already have demonstrated their utility to FNSI efforts while others hold promise for transformational change of FNSI.

3. Emergence of novel methods

Broad trends in ICT have given rise to a constellation of technologies, systems and approaches which are influencing the ways in which food systems and food and nutrition security are assessed and influencing the development of the next major evolution of FNSI.

3.1. Social computing, crowdsourcing and open source development models

Social networking and the proliferation of facile real-time communication tools is enabling broad, semi-formal, inter-institutional networks to organize, thereby enhancing their ability to make significant and complex contributions to information systems (Shirky, 2008). Contemporary social networking enhances data and knowledge sharing and enables efficient utilization of the so-called “long tail” of contributors, the people who contribute to projects only rarely and for very specific purposes. Open source development models built upon distributed collaboration are becoming increasingly competitive in their ability to generate high quality software and systems in a bottom–up fashion. Social computing enables crowdsourcing—that is, the direct engagement of end-users and broad sets of stakeholders in the development and maintenance of systems and datasets which they use. Related to this, a new generation of “micro-tasking” platforms (e.g. CrowdFlower and Amazon Mechanical Turk) are specifically designed to efficiently harness the power of online workers by enabling the systematic distribution and coordination of short duration tasks such as translating text messages, for example.

Crowdsourcing and micro-tasking tools have tremendous potential to impact the speed and efficiency of the decision support value chain (Fig. 1), particularly at the data capture and curation steps. For FNSI, crowd-driven information systems may be particularly relevant in environments which present significant obstacles to conventional assessment methods, for instance in failed states where security concerns may make it difficult to operate a data collection team. Similarly, they could play a role in information-starved, post-crisis environments where early data is critical and where the main focus tends to be on acute rather than chronic food insecurity. Local networks of affected community members are the earliest and often the highest impact responders in crisis environments. As a group they have the earliest reliable information as well as the most urgent information requirements.

The Mission 4636 project, for example, was an effort to collect early crisis information from Haitians affected by the January 2010 earthquake using mobile text messaging and micro tasked translation of messages via CrowdFlower (Munro, 2012). Within days of the earthquake thousands of text messages containing rich situational data were being sent to the 4636 short code by the affected population. Within the first month tens of thousands of messages had been translated, categorized (e.g. food needs, food available) and geocoded by the massive global network of Haitian Diaspora and Creole-speakers that Mission 4636 had assembled. Within 5 days of the earthquake—long before any conventional rapid food security assessment was feasible—the Ushahidi Haiti Project had started mapping the data on a public-facing Crisis Map (Fig. 2). The work was done almost entirely by volunteers, and the information generated was used by analysts/humanitarians, local organizations and individuals to gain rapid situational analysis and in some cases to inform the deployment of humanitarian relief (Morrow et al., 2011). Mission 4636 and the Ushahidi Haiti Project were focused on process crisis information, but this process model of using crowdsourcing techniques and micro-tasking systems to engage local crisis-affected populations and leverage the volunteer community could also be used to assemble rich, early databases specifically focused on acute post-crisis food security information.

It should also be noted that even in scenarios where members of the crowd cannot see the personal or community benefits of participation in a crowdsourcing project—or are less compelled by crisis circumstances to participate—micro-tasking systems are also able to incentivize contributions of work using financial or other rewards.

3.2. Cloud–mobile systems and open standards

Centralized, web-based approaches to computing and data management create tremendous potential for synergistic activities and data sharing among users of the cloud. Cloud infrastructure is commonly made accessible to individuals and organizations as subscription-based web applications or “software-as-a-service” (SaaS). Services are often packaged as suites of optional modules and tiered pricing schemes employed depending on level of usage.

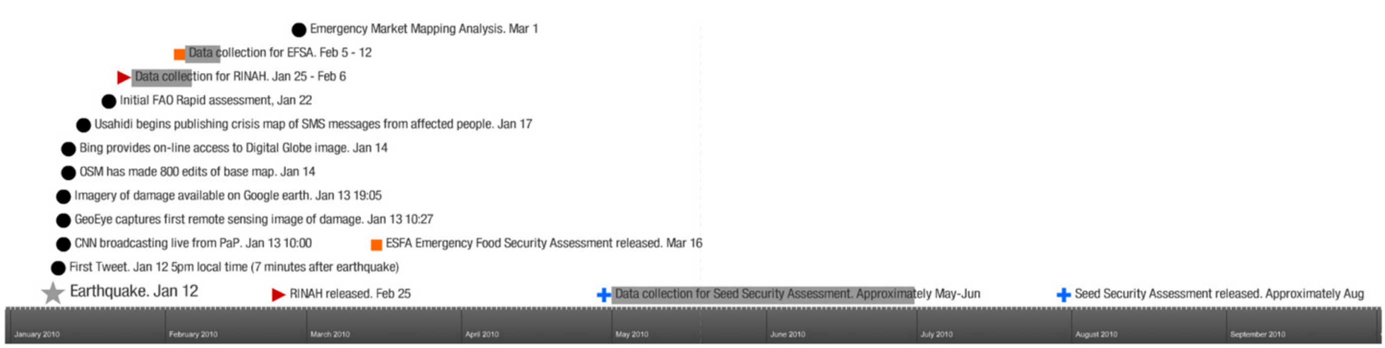

Fig. 2. Timeline of key information events after the 2012 quake in Haiti. Circles refer to notable information events. Other shapes indicate various data collection activities and their corresponding report release dates.

In many cases basic usage and access to a limited set of core modules is available for free. Such cloud-hosted applications remove much of the burden of hardware/software system setup and maintenance and allow end-users to focus on use. This is having an impact on the information value stream by making powerful tools for curating, visualizing and analyzing data available and usable to specialists and non-specialists alike. Cloud-hosted geospatial data platforms such as Geocommons furnish end-users with basic web based geospatial analysis tools, standards-compliant data storage and data-sharing/dissemination opportunities in a cloud environment. Basic services are available free of charge. Tableau and IBM's ManyEyes work on a similar model designed to facilitate the display and interactive visualization of text and tabular data on the web. Google's suite of cloud-based productivity tools such as Docs and Spreadsheets constitute an extremely user friendly database and data visualization kit facilitating distributed collaboration. These cloud-hosted systems are generally simple enough for non-technical users to engage, but bring efficiencies to the information value stream which appeal even to highly sophisticated information workers.

Centralization of computing capability becomes particularly powerful when combined with the widespread proliferation of smart mobile devices. "Human sensors" can dynamically update data bases using sophisticated handheld devices or even basic cell phones. It is estimated that there will be more mobile-connected devices than people on Earth by the end of 2012 (Cisco, 2012). In the poorest countries, many people share or rent mobile communication devices. It was estimated that over 75% of people in Haiti had access to a mobile phone at the time of the earthquake (UNDP, 2011). Wireless providers in Somalia offer the lowest international call rates in Africa (CIA, 2012). Globally, one in eight mobile phone users now has access to the Internet on a mobile device (UN ITU, 2010).

Rapid innovation in the mobile realm has led to burgeoning SMS-based data collection tools like RapidSMS (for sending, receiving and managing mobile text message data) and OpenDataKit that enable the development and deployment of smartphone-based data entry forms. SMS-based data systems provide easy ways to enter and screen data in the field and receive instantaneous or scheduled analysis and feedback to field personnel, greatly enhancing efficiency of the value stream. Today, an Android-based Smartphone capable of running the free and open source data collection applications (apps) can be acquired for under $100. Such devices have the ability to capture geographic coordinates and multimedia, transmit it to a centralized database on a server or the cloud via Wi-Fi or SMS, and the software can often be managed by non-specialists with a minimal amount of training. Ushahidi, the previously-mentioned crowdsourcing and crisis mapping software deployed after the Haiti earthquake in 2010, is now packaged with modules for data collection and dissemination via mobile phone and smartphone applications. It is now offered as a free cloud-hosted web application (crowdmap.com) oriented to non-technical users, supporting data import, export and sharing features based on open standards.

3.3. Big data and digital signals

Social data—that is, the data we are generating about ourselves and sharing with each other on social networks like Facebook and Twitter—in combination with observed and transactional data like weather monitoring and credit card usage is amounting to an extremely large body of data commonly referred to as "Big Data". There is much interest in mining and monitoring this kind of data for "digital signals". For example, in Rwanda, cell phone time consumption patterns promise to be good and real time proxy indicators of household cash liquidity (Blumenstocky et al., 2011). Some of this data is easily accessible public information on the web or at least easily accessible through data sharing and use agreements with respective public or private data stewards. Challenges to use tend to be due to the lower capacity of analytical processes to deal with the sheer size of the databases, or the non-standard formats. For example, big data often takes the form of unstructured or semi-structured textual events like chat forum proceedings or SMS text message archives. To begin to make sense of this kind of information, advanced visualization analytics and techniques in the realm of language processing are extremely important.

The UN's Global Pulse initiative has collaborated in conducting research into the use of big data for monitoring digital signals in health, development and crisis detection domains. One project relevant to FNSI entailed the construction of a daily bread price index for six Latin American countries, based on price information automatically extracted from information published by retailers on the web. Fig. 3 illustrates the potential utility of the approach based upon an analysis of bread prices in Uruguay. Furthermore, the online prices can be checked and tabulated on a daily instead of monthly basis, enabling faster change detection. Similarly, a Global Pulse project conducted in Indonesia with the collaboration of Crimson Hexagon, a social media analytics company, revealed that food related tweets on the Twitter social network correlated with real events, and that the number of tweets about the price of food correlated with food price inflation (Fig. 4).

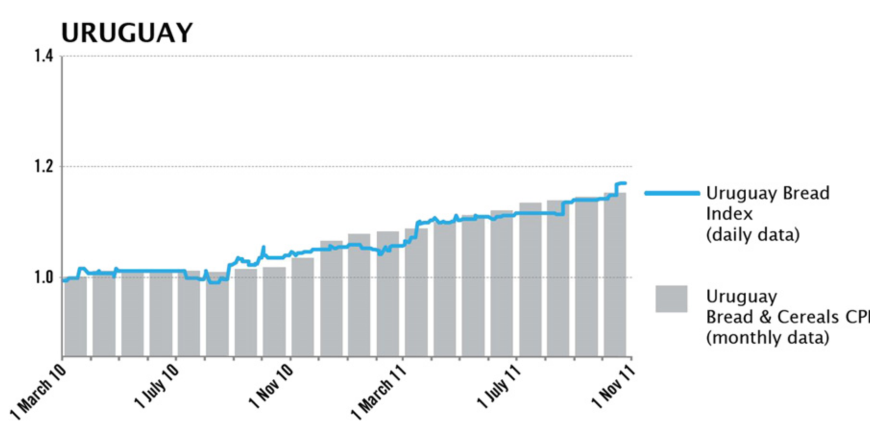

Fig. 3. Price of bread in Uruguay as estimated via an online bread prices index and the traditional bread and cereals consumer price index. *The daily e-bread index was built on data extracted from online retailers from 1st March 2010 to 1st November 2011 and shows the change in prices of bread (normalized to the 1st March).*
Source: Re-published from UN Global Pulse and PriceStats (2011).

Monitoring digital signals in big data may be particularly relevant for capturing information during acute shocks, where there is significant interest in increasing the timeliness and geographic disaggregation of FNSI, especially during periods of civil unrest and instability (Lagi et al., 2011).

3.4. Gaps and challenges

The application of novel methods to FNSI is an emergent phenomenon. Much remains to be done to maximize the value added of these methods. A number of issues remain:

- *The continued availability/access constraints to broadband internet connections.* Though cellular phone penetration is very high among many food and nutrition insecure populations, access to broadband internet is very limited (either because of availability or cost). The full benefit of novel methods is still limited to major metropolitan areas and among the affluent.
- *The generation and use of "open data" can introduce potential issues of protection.* Many novel assessment techniques rely on the concept of shared, open data. A high degree of openness and data-sharing is critical in order to establish and maintain the network of stakeholder-contributors for crowdsourcing activities, for instance. However, openness can generate significant issues of privacy and protection when sensitive aspects of the data are not controlled, such as the precise locations of vulnerable groups or the specific names or contact information for individuals who may not have implicitly or explicitly granted permission to publish it (Morrow et al., 2011). Furthermore, individual bits of publically accessible information scraped from the web—popularly referred to as our "digital exhaust"—may often seem trivial from a protection standpoint; however, when this information is aggregated, organized and analyzed as "big data" for specific purposes it can reveal far more about a particular individual or a particular local population than they might intend.
- *Time, energy and creativity are required to connect conventional FNSI efforts and novel methods.* In the case of Haiti, novel assessment activities like Mission 4636 were considered to be shadow systems and not complementary tools. Much work is needed to build bridges between the data provider and user communities of these two distinct sources of FNSI.
- *Novel assessment methods can be used to help develop more rapid and efficient probability survey methods.* The use of smart phones and cloud-hosted analytics makes it possible to begin to compare the quality and efficiency of larger scale survey efforts that collect numerous data elements to more parsimonious surveys that capture information on a finer scale and more frequently. This type of research should be undertaken.
- *Further development is needed to adapt the format and type of FNSI specifically to the needs of national institutions and communities as well as other coalitions and groups* such as academia, the private sector, and professionals that contribute to FSN outcomes. Strengthening communication between knowledge producers and decision makers by targeting FNSI to a broader number of stakeholder audiences, a common weakness of conventional FNSI, also has not been adequately realized for novel methods.
- *To date, systematic refinement of FNSI though real-time feedback has not taken place.* New technologies are offering feasible ways for different stakeholders not only to contribute primary information for analysis but also to provide feedback through two-way communication. Real-time feedback loops have the potential to improve the accuracy and more importantly the relevance of FNSI to decisions for different stakeholders. The widespread use of social media and techniques such as polling in the media and areas outside food and nutrition security suggest that greater FNSI stakeholder engagement is both possible and may indeed be an area of great latent demand.

4. Conclusions

FNSI for decision support is evolving rapidly and novel methods of data capture, curation, analysis and communication are beginning to transform efforts towards a dynamic and near real-time FNSI complex adaptive information system.

The increasing ability to utilize more directly the capabilities of human sensors with five senses and the ability to interpret the information in context is a profound development. Including spatial attributes and scale with mobile technology, these sensors are massively networked. Those who are nearest to the problem

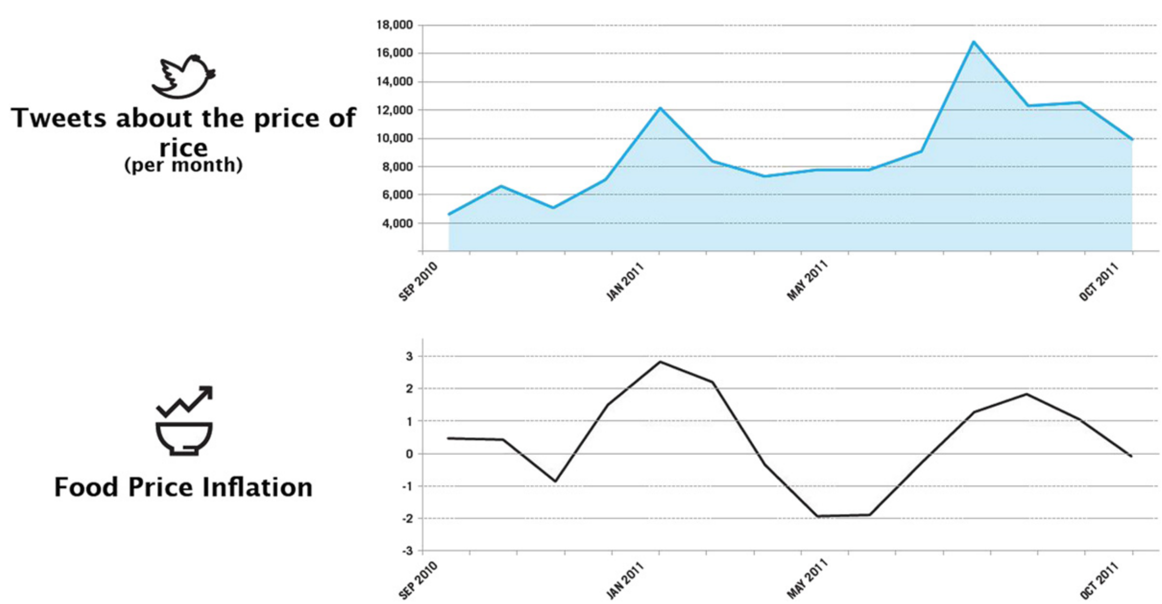

Fig. 4. Twitter activity of Indonesians and food price inflation. Figure shows the volume of tweets per month about the price of rice from October 2010 to October 2011 in Bahasa Indonesia/Javanese and monthly inflation rate for the food basket in Indonesia from October 2010 to October 2011.
Source: Re-published from UN Global Pulse and Crimson Hexagon (2011).

increasingly will have powerful information available to propose and implement solutions. The information feedback loops that can lead to highly contextualized and intelligent problem solving behaviors have the potential to revolutionize FNSI.

Similarly, novel sources of information, such as big data, promise to deliver dynamic information in the place of previously static indicators related to socioeconomic status, migratory patterns and market dynamics.

More sophisticated and user friendly analytics enable stronger triangulation of indicators and the potential for evaluating the behavior of perception measures in relation to other data sources.

However, many challenges and gaps remain, including operational research, internet bandwidth, and building cultural bridges between the youthful technological community promoting modern methods, affected communities and the seasoned conventional development/humanitarian policy and program makers.

Perhaps the greatest unrealized potential of the emergent FNSI and novel methods of assessment is the ability to communicate with a wider variety of stakeholders providing more tailored FNSI and integrating real-time feedback, ultimately improving relevance to FNSI end users.

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