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Examining the Role of Information and Communication Technologies to Improve Food Security Management: The Case in Oregon

CAPSTONE REPORT

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Abstract

This annotated bibliography describes information and communication technologies in use around the world that can be applied to the growing food insecurity problems in Oregon. Articles written since 2000 are reviewed to identify technologies that can be implemented to positively affect food security and to support policy recommendations. Topics include ICT infrastructure, GIS mapping, and agricultural information and knowledge management. Tools include information and knowledge networks, accessible databases, community food assessments, and food traceability systems.

keywords: agroecology, food desert, food insecurity, food safety, food security, geographic information systems (GIS), geospatial information technology, information and communication technology (ICT), information management, knowledge management, natural resource management, precision agriculture, spatial data, traceability

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Introduction

Problem

Food security is defined as “when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life” (“Food Security”, 1996, para. 1). Food insecurity and hunger result when there is a lack of access to safe and nutritional foods (Gareau, 2004). In 1998, 9.7% of households in the United States did not have enough food to meet basic needs (Gareau, 2004); by 2008, that percentage had risen to 14.7% (“Household Food Security,” 2009). The Oregon Department of Agriculture (“Household food security drops in Oregon and US,” 2010) states that 14.6% of Oregon households do not have consistent access to food. During the 2010-2011 fiscal year, more than 260,000 Oregon residents each month (33% of whom were children) ate meals from an Oregon Food Bank food box, an increase of 29% since 2008 (“2010-2011 Annual Statistics”, 2011).

Hoffman (2000) states that the Internet is “the most important innovation since the development of the printing press" and that it will "radically transform not just the way individuals go about conducting their business with each other, but also the very essence of what it means to be a human being in society" (as cited in Kamssu, Siekpe, & Ellzy, 2004, p. 152). According to Chowdhury (2001), Information and Communication Technologies (ICT) “store, process, share, display, protect, and manage information” (p. 12). ICT is one of the fastest growing industries in the world, and access to ICT can enable small farmers to participate in the global market, thus increasing food supply and access (Chowdhury, 2001). Lashgarara, Mirdamadi, Hosseini, and Chizari (2008) identify several ways in which ICT can be used to increase food security, including (a) increasing access to real-time market information, (b) fostering agricultural diversification, and (c) increasing the knowledge base of small agricultural businesses by improving access to global knowledge bases, including the world wide web (p. 70). McLaren et al. (2009) state that ICT can help eliminate the *last mile* problem often found in rural areas, which refers to the expense and effort related to delivering connectivity to customers who are spread out geographically (“Last mile,” 2011). Addressing this problem will be one of the means to achieving the goal of increasing access to knowledge and real-time market information suggested by Lashgarara et al. (2008). For example, geographic information systems (GIS) can be used to provide spatial mapping of food access (one of the important markers of food security), as well as more sophisticated analyses of food price and availability (McEntee & Agyeman, 2010).

As noted by Hwang and Smith (2010), ICT and GIS can have a positive influence on food security when utilized within a web mapping framework. By using GIS and global navigation satellite systems (GNSS) and integrating with technologies that promote communication between farm implements, tractors, and computers, protocols have been developed that can trace food from the source to the market (Gebbers & Adamchuk, 2010). Gebbers and Adamchuk (2010) believe that this merger of communication and GIS, and the management of the information gathered, will optimize production and help ensure that food supplies are correctly routed to meet current demands.

Knowledge management systems (Brown & Duguid, 2002), specifically the utilization of databases populated by information gathered via GIS (Ostry & Morrison, 2009), web mapping frameworks (Hwang & Smith, 2010), and information gathered through precision agricultural systems (Gebbers & Adamchuk, 2010), combine information and communication technologies with geographic information and navigation systems. This combination of technologies allows information to be used effectively (Brown & Duguid, 2002) to improve food security by crossreferencing the information gathered by the various technologies with the hunger indices identified by Masset (2011).

Purpose

The purpose of this annotated bibliography is to identify and describe the most promising information and communication technology tools that can be used to support knowledge management related to food security (Chowdhury, 2001; Deichmann & Wood, 2001; Gareau, 2004). Specifically, these tools can be used to (a) identify practiced methods of tracking access to market information (Chowdhury, 2001) and (b) increase the ability to track and report on regional resources (Deichmann & Wood, 2001). As a key example, GIS can be used to analyze and track food availability based on grocery stores and other fresh food markets per capita (Eckert & Shetty, 2011; McEntee & Agyeman, 2010; Russell & Heidkamp, 2011). GIS can also contribute to crop cycle planning in order to sustainably optimize growing seasons and yield, as well as enhance food traceability (Gebbers & Adamchuk, 2010). In addition, GIS can help predict environmental impact of changes to the global food system and management decisions (Zaks & Kucharik, 2011; Wu, Tang, et al., 2011; Wu, Yang, et al., 2011).

Research Questions

This annotated bibliography presents literature that examines how information and communication technologies can be used to better manage food security; emphasis is on the situation in the state of Oregon in the Unites States of America. It is further suggested that an assessment of the effectiveness of the implementation of the selected tools should be measured via survey instruments developed based on the Action Aid Hunger Index as described by Masset (2011) and utilizing the instruments described by Keenan, Olson, Hersey, and Parker (2001).

The annotated bibliography is organized around the following concepts, framed as research questions:

Main question. How can existing information and communication technologies, particularly GIS and knowledge management systems, be used by the State of Oregon to increase food security?

Subquestions.

1. Studies have shown that information and communication technologies can be instrumental in increasing food security (Gareau, 2004). What specific ICT tools and approaches have proven to be the most effective in reducing food insecurity?
2. Geographic information systems (GIS) provide unique mapping tools and provide useful data for the analysis of geographic and socioeconomic food accessibility (Deichmann & Wood, 2001) as well as the identification of food deserts (Eckert & Shetty, 2011; McEntee & Agyeman, 2010; Russell & Heidkamp, 2011), both of which can contribute to more efficient food production and distribution systems. How can GIS technology be effectively used to improve production and distribution of existing food sources?
3. Food safety is an important aspect of food security and can be better administered through information systems that manage food traceability (Golan et al., 2004) and aid in making "informed decisions about agricultural productivity" (Zaks & Kucharik, 2011). What kinds of knowledge management systems could be effectively implemented to increase food safety and security?

Audience

The intended audiences for this annotated bibliography are statewide food policy councils, government agencies that deal directly with food security and policy, and non-profit agencies that work with food security. In particular, this study is designed for these professionals working within the state of Oregon. There are three regional food policy councils in Oregon (Council List, n.d.). The largest one, Portland-Multnomah Food Policy Council (n.d.), is a “citizen-based advisory council” (para. 1) that works directly with officials from both the City of Portland and Multnomah County. This council addresses different aspects of food security including (a) land use and food policy, (b) food access and education, (c) school food, and (d) local and regional purchasing plans. These citizen-councils are the link between community and government, and are responsible for bringing “citizens and professionals together” (Portland Multnomah Food Policy Council, n.d., para. 1). This advisory council, as well as the others Oregon regional councils, works directly with the city and county governments to advise upon food policy and develop projects that encourage a “strong economy of local food producers and consumers” (Land Use and Food Policy, n.d., para. 1).

Specific groups in Oregon include, but are not limited to: (a) the Portland-Multnomah Food Policy Council, (b) the City of Portland’s Bureau of Planning and Sustainability, (c) the Lane County Food Policy Council, (d) the Central Oregon Food Policy Council, (e) the Oregon Food Bank, and (f) the Oregon Department of Agriculture. Although focus is on the state of Oregon as a specific context, the assumption is that this study will be of value to similar groups in other states across the country. The report will be distributed to the citizen advisory groups, and the directors of each of the government agencies, and the program directors for any relevant non-profits, each of whom is responsible for advising policy on food procurement or distribution.

Significance

According to Gareau (2004), “a potential tool in the fight against food insecurity and hunger is information technology (IT), since its use and range of application continue to grow at astonishing rates” (p. 273). The use of information and communication technology (ICT), specifically GIS, has proven vital to improving food security by providing greater access to these types of data: (a) precision farming (Gebbers & Adamchuk, 2010), (b) food traceability (Golan at al., 2004), and (c) food desert mapping to inform hunger patterns and food access statistics (McEntee & Agyeman, 2010). The use of information and communication technology also increases the ability to track and report on a region’s resources (Chowdhury, 2001).

The lack of appropriate technology can be said to contribute to increased food insecurity (Gareau, 2004). Gareau (2004) expands on this concept by citing a case in rural Mississippi where at least five organizations work to provide food assistance with little coordination between organizations. The lack of networking and information sharing hinders the community’s overall efforts. Distribution is duplicated in some areas and absent in others; in addition, the lack of communication and coordination opens up the systems for abuse (Gareau, 2004).

Zaks and Kucharik (2011) state that ICT is likely to play a much greater role in food management and traceability. The United States Department of Agriculture has recently begun providing satellite data through their Crop Explorer Tool, as well as other satellites, in an effort to provide high-level spatial mapping to assist in agricultural monitoring. This in turn requires new technologies to be implemented, and new knowledge management systems to be developed (Zaks & Kucharik, 2011).

Delimitations

Time frame. Due to the changing landscape of information technology and knowledge management, references are limited to those published since 2000, which corresponds to the expansion of civilian satellite signals that can be utilized for agricultural GPS and GIS ("Precision, geospatial & sensor technologies," 2011).

Selection criteria. The literature is selected from the results of searches conducted in both Google Scholar and the University of Oregon (UO) library databases. Preference is given to (a) those authors with documented and relevant expertise who are cited in other works by their peers, (b) the presence of the publication in a peer-reviewed journal, and (c) the specific focus on relevant information and communication technologies (Bell, 2009). In addition, government publications specifically related to agriculture and food security are considered valid sources as long as they are clearly identified as such, and the authors of said publications are considered experts in their fields (Bell, 2009).

Preference is given to resources that are available electronically, although exceptions are made for publications with abstracts that add significantly to the body of literature and that are available through the University of Oregon library system.

Focus. The main searches are conducted based on the primary keyword search phrases (a) food security [and] information and communication technology (Gareau, 2004), (b) food security [and] geographic information systems (Eckert & Shetty, 2011; McEntee & Agyeman, 2010), and (c) food security [and] knowledge management (Gebbers & Adamchuk, 2010; Golan et al., 2004; Zaks & Kucharik, 2011). Although some of the identified sources also address sustainability as it relates to food security (Chowdhury, 2001; Deichmann & Wood, 2001; Gebbers & Adamchuk, 2010), this annotated bibliography does not focus on the sustainability aspect of food security. In addition, due to the long list of unanticipated effects of genetically modified (GM) foods and the lack of studies proving the safety of GM foods (Haslberger, 2003), genetically modified and transgenic foods are not considered a viable technology as relates to food security. Other interrelated causes of food insecurity, such as socioeconomic or educational/informational causes are not addressed (McEntee & Agyeman, 2010).

Audience. The intended audiences for this annotated bibliography are statewide food policy councils and government agencies that deal directly with food security and policy within the state of Oregon, the author's state of residence.

Measures of effectiveness of selected ICT tools. The two main indicators of hunger according to the United Nations (UN) as reported by Masset (2011) are "the prevalence of underweight children and the proportion of the population below a minimum level of energy consumption as calculated by the FAO [Food and Agriculture Organization]" (p. S102). For the purposes of this annotated bibliography, these indicators of hunger are proposed as the standard measurement of the effectiveness of selected tools suggested as ways to alleviate food insecurity. The Action Aid Hunger Index looks at not only the UN indicators, but also four other dimensions, including "legal commitment to the right to food; investments in agriculture; investments in social protection; and hunger outcomes" (Masset, 2011, p. S105). Since this existing index most closely matches with the goals of using ICT, GIS, and knowledge management to increase food security, this is the most relevant existing hunger index for use in this study.

Keenan et al. (2001) outline instruments available to measure food security to determine the hunger index for a region based on individuals and/or households. These survey instruments could be developed with the Action Aid Hunger Index as a valid tool for developing a baseline measurement of food security within the target region (Oregon) as well as periodic measurements to determine the effectiveness of the proposed tools. However, further development of the instruments is not within the scope of this annotated bibliography.

Masset (2011) offers an analysis of various hunger indices derived from the two above-named indicators, as well as suggestions for developing a custom hunger commitment index (p. S107). However, for the purpose of this annotated bibliography, further investigation of this analysis is also beyond the scope.

Reading and Organization Plan Preview

In order to ensure that each selected reference is treated similarly and reviewed thoroughly in relation to the purpose and goals of this study, the following steps are followed in the reading and analysis process:

1. Each article abstract is scanned to determine initial relevance to the larger topic of food security for this study (The World Food Summit, 1996).
2. The abstract and citation information are collected in a spreadsheet and initially sorted by preliminary comparison to the purpose of this study.
3. The first author of each article is researched to determine expertise (based on the standards referenced in the selection criteria for this study) (Bell, 2009).
4. Resources that are determined to be relevant in relation to the main research question in this study are printed and read to ensure continuing relevance and evaluated using the extended evaluation criteria outlined in the research strategy section (Bell, 2009).

5. Key sections are highlighted and notated in the reference spreadsheet based on relevance to the specific sub-questions in this study in a process similar to content analysis (Busch et al., 2005).

The organizational structure for the presentation of information in the Annotated Bibliography is thematic (University of North Carolina, n.d.). Each reference selected for inclusion in the Annotated Bibliography section of this paper is sorted again based on its relevance to one of three organizational themes, which equate to concepts reflected in the three sub-questions addressed in this study including (a) food insecurity and information and communication technology tools (Chowdhury, 2001; Gareau, 2004), (b) geographic information systems and production and distribution of food (Deichmann & Wood, 2001; Eckert & Shetty, 2011; McEntee & Agyeman, 2010), and (c) food safety and security and knowledge management systems (Gebbers & Adamchuk, 2010; Zaks & Kucharik, 2011).

Definitions

In fields outside of agriculture and geography, words such as *security* and *safety* have several connotations. Due to the potential for confusion between *food security*, *national security*, or *food safety* and *personal safety*, definitions are provided for those words than may lie outside of the common language (Creswell, 2009). The definitions are selected from the references highlighted in this annotated bibliography as well as articles that address similar ideas to ensure that words and phrases are used consistently throughout the study (Creswell, 2009).

Agriculture innovation systems – These systems strengthen "the capacity to innovate throughout the agricultural production and marketing system" through "combinations of technical and institutional innovations throughout [agricultural] production, marketing, policy research and enterprise domains" (Pound & Essegby, 2008, p. 50)

Agroecology – the study of the ecological impacts of agricultural production (Zaks & Kucharik, 2011).

Agroecological sensor web – A monitoring system that assists in the "analysis and reporting of spatial and temporal variability across agroecological landscape" (Zaks & Kucharik, 2011, p. 2). Such systems will gather data from three main observational components: (a) "remote (e.g. satellite, aircraft, unmanned drone)," (b) "automated *in situ*," and (c) "direct human observations" (Zaks & Kucharik, 2011, p. 5).

Choropleth map – A map "in which areas are shaded or patterned in proportion to the measurement of the statistical variable being displayed on the map, such as population density or per-capita income" ("Choropleth Map," 2011, para. 1).

Community Food Assessments (CFA) – "Activities to systematically collect and disseminate information on selected community characteristics so that community leaders and agencies may devise appropriate strategies to improve their localities. [They] have informed traditional activities in comprehensive, land-use, and sectoral planning, as well as more recent efforts to promote sustainable and healthy communities" (Pothukuchi, 2004, p. 356).

Community food security (CFS) – According to Hwang and Smith (2010), this "includes community-level characteristics alongside census-type data to provide a more holistic assessment of the factors driving food insecurity in a particular geographic area" (p. 2) and is further defined by Hamm and Bellows (2003, p. 37) as the assurance that "all community residents obtain a safe, culturally acceptable, nutritionally adequate diet through a sustainable food system that maximizes community self-reliance and social justice" as cited by Hwang and Smith (2010, p. 3).

Food desert – Defined by the Department of Health (1996) as "areas of relative exclusion where people experience physical and economic barriers to accessing healthy food'' as cited by McEntee and Agyeman (2010, p. 165).

Food insecurity – "Food insecurity, and its extreme form, hunger, occur whenever the accessibility to an adequate supply of nutritional and safe foods becomes restricted or unpredictable" (Gareau, 2004, p. 273).

Food safety – Standards of practice by "growers, processors, retailers, restaurateurs and other sources" that develop from established practices as well as religious and ethnic customs that ensure that available food is unlikely to cause harm (McGill, 2009, p. 403).

Food security – "When all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (The World Food Summit, 1996, para. 1).

Food system – "A set of dynamic interactions between and within the biogeophysical and human environments which result in the production, processing, distribution, preparation and consumption of food" (Gregory, Ingram, & Brklacich, 2005, p. 2141).

Food traceability – "Record keeping systems designed to track the flow of product or product attributes through the production process or supply chain" with the primary objective to "improve supply management; to facilitate traceback for food safety and quality; and to differentiate and market foods with subtle or undetectable quality attributes" (Golan et al., 2004, pp. 1, 4).

Geographic information systems (GIS) – "Systems to store, manage, and analyze geographically referenced data" (Deichmann & Wood, 2001, p. 14).

Geoidentifier – A solution "for coding the location of a production unit…" specifically, "a string of 22 characters that can readily be converted into a barcode… easily decode[d] in order to determine the geographical origin of a lot precisely" (Oger, Krafft, Buffet & Debord, 2010, p. 638).

Geoparsing – "The process of recognizing geographic entities from unstructured textual documents and data from other mediums such as audio content" (Hwang & Smith, 2010, p. 6).

Geospatial database – A "type of database [that] can be updated to monitor changes in agricultural land use by region and can be supplemented with other data. This tool could also be used to produce easily accessible web-based maps and other educational outputs for use by various stakeholders" (Ostry & Morrison, 2009, p. 21). Ostry and Morrison (2009) propose that this type of database would contain information on "what foods are produced, under what financial and agricultural conditions, and in what quantities" (p. 19) and would report on the data in definable geographic areas.

Geotraceability – “The ability to trace, with the aid of specific management systems, geographical information linked to traceability information, all along agro-food chains. [It] combines the functionalities of a conventional traceability system and the functionalities of a geographic information system in order to enhance the traceability information by placing it in its agri-environmental context” (Oger et al., 2010, p. 5).

Global navigation satellite systems (GNSS) – Technology that uses satellites to provide global geo-spacing positioning to increase awareness of soil conditions (Gebbers & Adamchuk, 2010) and uses “airborne data collection systems that provide periodic land use, land cover, and other thematic information (aerial photos and satellite remote sensing)” (Deichmann & Wood, 2001, p.14).

Global positioning system (GPS) receivers – “Devices that measure geographic location” (Deichmann & Wood, 2001, p.14).

Hunger index – A measurement of hunger based both on the causes of hunger: (a) lack of food availability and (b) low food intake, as well as the consequences of hunger: (a) child mortality and morbidity rates, (b) low cognitive development, and (c) stunted growth patterns (Masset, 2011).

Information and communication technology (ICT) – Tools that “capture, store, process, share, display, protect, and manage information” (Chowdhury, 2001, p.12).

Knowledge management – “The use of technology to make information relevant and accessible wherever that information may reside. [It] incorporates systematic process of finding, selecting, organizing, and presenting information in a way that improves…comprehension…” (Brown & Duguid, 2002, p. 117).

Last Mile Problem – “The final leg of delivering connectivity from a communications provider to a customer…typically seen as an expensive challenge because "fanning out" wires and cables is a considerable physical undertaking” (“Last mile”, 2011, para. 1).

Millennium Development Goals – “[E]ight goals - each with specific targets and indicators - are based on the United Nations Millennium Declaration, signed by world leaders in September 2000. They commit the international community to combating poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women” (Millennium Development Goals, n.d., para. 2).

Participatory mapping – Maps created when specialists work directly with communities to create “spatial inventories of natural resources, property status, land-use rights, and perceived problems” (Deichmann & Wood, 2001, p. 14).

Precision agriculture – A type of agriculture that “comprises a set of technologies that combines sensors, information systems, enhanced machinery, and informed management to optimize production by accounting for variability and uncertainties within agricultural systems” (Gebbers & Adamchuk, 2010, p. 828).

Radio frequency identification (RFID) – An “innovative noncontact automatic identification technology [designed] to read and write…data on electronic media…more quickly and accurately” (Sugahara, 2009, p. 2296).

Spatial profiling – A mapping system that supports multiple methods of distribution and “which provides geographic information to enhance targeting of areas and populations most vulnerable to food insecurity” (Hwang & Smith, 2010, p. 2).

Traceability system – "Traceability systems are a tool to help firms manage the flow of inputs and products to improve efficiency, product differentiation, food safety, and product quality" (Golan et al., 2004, p. i).

Web mapping framework – A framework "which integrates a variety of publicly available software tools to enable spatial exploration…for informing food insecurity issues" (Hwang & Smith, 2010, p. 2).

Research Parameters

This section describes the methods used to design the annotated bibliography. This design consists of several components, including (a) an outline of the search strategy (including listing key words and the search strings used); (b) a documentation strategy to formalize how results are saved, sorted, and used; (c) a set of evaluation criteria that describe the formal assessment process each article goes through before final inclusion in the annotated bibliography; and (d) the reading and organization plan that details the in-depth reading and conceptual analysis process used to identify key information for presentation in the annotated bibliography.

Search Strategy

The literature searches are conducted in both Google Scholar and the University of Oregon (UO) library databases. These searches are conducted in three primary areas: (a) food security and information and communication technology (Ballantyne, 2009; Chowdhury, 2001; Gareau, 2004; Ingram, 2011; Kamssu et al., 2004; Larsen, Powell, Sriskandarajah, & Peterson, 2010; Lashgarara, Mirdamadi, & Hosseini, 2011; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; McLaren et al., 2009; Yaghoobi & Sarani, 2011), (b) food security and geographic information systems (Charreire et al., 2010; Deichmann & Wood, 2001; Eckert & Shetty, 2011; Gregory et al., 2005; Hwang & Smith, 2010; McEntee & Agyeman, 2010; Ostry & Morrison, 2009; Pothukuchi, 2004; Russell & Heidkamp, 2011; Wu, Tang, et al., 2011; Wu, Yang, et al., 2011), and (c) food security and information and knowledge management (Altieri, 2002; Brooks & Loevinsohn, 2011; Gebbers & Adamchuk, 2010; Golan et al., 2004; Nah & Chau, 2010; Oger et al., 2010; Popper, 2011; Sugahara, 2009; Zaks & Kucharik, 2011). In each of the three primary search areas, the following results are noted from a search in the UO Library:

1. Food insecurity and information and communication technology: 78 results, 75 of which are in the targeted time frame of 2000-2011
2. Geographic information systems and the production and distribution of food: 98 results, all of which are in the targeted period of 2000-2011.
3. Food safety and security and knowledge management: 105 results, 102 of which are in the targeted period of 2000-2011.

Key words. A list of keywords is developed from the results and the search is further refined in the Agricola (AGRICultural OnLine Access) database, the Geobase (a collection of indexed research literature on the earth sciences, including geology, human and physical geography, and environmental science) database, the Web of Science database, and the Science Direct search engine through Elsevier.

- Agriculture
- Agroecology
- Communication technologies
- Food desert
- Food insecurity
- Food safety
- Food security
- Geographic information systems (GIS)
- Geographic management systems (GMS)
- Geospatial information technology
- Global Navigation Satellite Systems (GNSS)
- Information and communication technology (ICT)

- Information management
- Information technology (IT)
- Knowledge management
- Natural resource management
- Precision agriculture
- Spatial data
- Traceability

Initial searches are based on Boolean strings combining either food security or food insecurity with the basic subquestion topics, with separate searches for different arrangements of the words. For example, food security is paired with (a) information technology, (b) communication technology, (c) information and communication technology, and (d) ICT. Each key word is paired alternately with food security and food insecurity, and additionally with keywords relating to the relevant subquestion (for example, *food traceability* OR *knowledge management* AND *food security*).

Documentation. Initial search results are saved in either (a) the UO Library user account or (b) through the Zotero research collection tool embedded in a web browser. All electronically available results are stored in PDF format and tagged with the relevant subtopic theme. Each reference is entered into an Excel spreadsheet that tracks author, year of publication, Boolean string used to find said reference, area of thematic relevance, availability of full text, and that has a column for each of the evaluation criteria.

Evaluation Criteria

Each reference is evaluated based on the initial selection criteria established in the delimitations. In addition, the guidelines set forth by Bell (2009) and Hewitt (1998) are utilized, including (a) relevance, (b) quality, (c) objectivity, (d) authority, (e) currency, and (f) critical appraisal (Bell, 2009; Hewitt, 1998). Details follow.

Relevance. Initial relevance is determined by the article's abstract (Hewitt, 1998). In addition, the goals of the publication as outlined in the abstract are examined and compared to the goals of this annotated bibliography (Bell, 2009).

Quality. Initial quality is addressed by the article's presence in a peer-reviewed journal (Hewitt, 1998). In addition, each article's reference list is scanned to ensure that wide varieties of sources, including other peer-reviewed articles, are used (Hewitt, 1998). Each article is also evaluated based on grammar, spelling, and clear organizational structure (Bell, 2009).

Authority. Each author is evaluated based on his or her current affiliation, relevant degrees, and number of citations found (Bell, 2009). First authors are held to a higher standard than secondary and tertiary authors.

Currency. Currency is determined by publication date (Bell, 2009). As noted in the delimitations, strong preference is given to articles published since 2000, which corresponds to the expansion of civilian satellite signals that can be utilized for agricultural GPS and GIS (United States Department of Agriculture, 2011).

Objectivity. Objectivity will be determined by critical reading for bias (either stated or implicit), examining the article's stated and met goals, and ensuring that sources (particularly any sources not found in peer-reviewed journals) clearly state the organization's point of view on the content (Bell, 2009). Each article will also be appraised to ensure that multiple points of view and sources are represented (Bell, 2009).

Reading and Organization Plan

Reading plan. The reading plan describes the process used to conduct an in-depth reading of all references that pass the initial assessment using the set of evaluation criteria (Bell, 2009). Each reference is read and coded using key words and phrases that reflect concepts described in the research subquestions through a step-by-step process known as conceptual analysis (Busch et al., 2005). Phrases found in multiple references are evaluated to ensure that they have similar enough meanings to be categorized together, and words and phrases that are similar but not identical are similarly evaluated to determine if they can be grouped together (Busch et al., 2005). Predetermined key words and phrases are coded based on occurrence within each reference (Busch et al., 2005) to help determine the correct thematic area into which the reference falls.

The in-depth reading and coding is done initially with printed hard copies of each reference and notes taken directly on each reference, with an accompanying notebook for further elaboration if necessary (see Table 1 for a listing of key phrases or words as they relate to one of the three research sub-questions). After the initial reading, the data recorded in hard copy is transferred to an Excel spreadsheet that is designed to easily sort and filter information as needed to aid in the speed and efficiency that the data is examined (Busch et al., 2005). By coding first manually, and then transferring the information to an electronic sorting house, the opportunity for analysis is increased and the potential for errors is reduced (Busch et al., 2005). After completing the in-depth reading and coding, any data that is not coded will be deemed irrelevant and ignored for the purposes of the Annotated Bibliography (Busch et al., 2005).

Table 1

Coding Key

Question	Concept/Thematic category	Key word and phrases
What specific ICT tools and approaches have proven to be the most effective in reducing food insecurity?		
	Food insecurity and information and communication technology tools	agricultural development, agricultural information, agricultural research, appropriate technology, communication, communications technology, development, food security, hunger, information and communication technologies, information technology, infrastructure, innovation systems, internet, knowledge sharing, last mile, mobile phones, rural development, solutions of food security, telecommunication
How can GIS technology be effectively used to improve production and distribution of existing food sources?		
	Geographic information systems and production and distribution of food	agriculture, choropleth mapping , community food security, food desert, food insecurity, food production, food security, geocoding, geographic food access, geographic information systems (GIS), geographical data, geoidentifier, geoindicator, geospatial information technology, global navigation satellite systems (GNSS), informatics, local food/local food systems, open source/open access, spatial analysis, thematic mapping, urban planning, web mapping
What kinds of knowledge management systems could be effectively implemented to increase food safety and security?		
	Food safety and security and knowledge management systems	agricultural innovation systems, agriculture, agroecology, food insecurity , food safety, food security, food traceability (traceability/tracing/ tracking/traceback), human tracking, information management, knowledge management, natural resource management, precision agriculture, product differentiation, quality of agricultural products, RFID, supply-side management

Organization plan. After completing the reading process, the coded information is sorted by relevance and relationship to the main question and the three subquestions that inform the themes of the Annotated Bibliography. The main question that is examined is “How can existing information and communication technologies, particularly GIS and knowledge management systems, be used by the State of Oregon to increase food security?" To answer that question, the Annotated Bibliography is divided into three distinct thematic sections, each of which is designed to answer one of the three sub-questions.

Theme one: Food insecurity and information and communication technology tools. This theme addresses the specific ICT tools and approaches that are used to effectively reduce food insecurity (Chowdhury, 2001; Gareau, 2004).

Theme two: Geographic information systems and production and distribution of food. This theme looks at how geographic information systems (GIS) are used to generate data to improve production and distribution of existing food sources (Deichmann & Wood, 2001; Eckert & Shetty, 2011; McEntee & Agyeman, 2010).

Theme three: Food safety and security and knowledge management systems. This theme examines the use of knowledge management systems to ensure food safety and thus improve food security (Gebbers & Adamchuk, 2010; Zaks & Kucharik, 2011).

Annotated Bibliography

The purpose of this annotated bibliography is to identify and describe the most promising information and communication technology tools that can be used to support knowledge management related to food security (Chowdhury, 2001; Deichmann & Wood, 2001; Gareau, 2004). The following set of 30 key references examines ways that food security is positively impacted by different types of information technology. Each annotation has four elements: (a) a bibliographic citation; (b) an explanation of the main points of the reference presented in an abstract; (c) a verification of credibility based on the evaluation criteria set up in this paper (refer to pages 17-18); and (d) a content summary of the reference and how it is applied in this study.

This annotated bibliography is divided into three themes, each addressing key concepts reflected in the research subquestions. These themes are: (a) food insecurity and information and communication technology tools; (b) geographic information systems and production and distribution of food; and (c) food safety and security and knowledge management systems.

Theme 1: Food Insecurity and Information and Communication Technology Tools

Ballantyne, P. (2009, November). Accessing, sharing and communicating agricultural information for development: Emerging trends and issues. *Information Development, 25*(4), 260-271. doi: 10.1177/0266666909351634

Abstract. The recent food crisis has helped to push agriculture and food security back on to national and development agendas. [This calls] for greater investment in knowledge creation, information access, and the wider use of information and communication technologies (ICTs). Agenda items include: The widening recognition of the value of farmer knowledge, growing use of information and communication technologies (ICTs) to enable different agricultural development activities, efforts to ensure that agricultural content is open and accessible, and some emerging new roles for agricultural library and information centers to meet changing demands.

Credibility. Peter Ballantyne is the head of knowledge management and information services for the International Livestock Research Institute. He has served as the President of International Association of Agricultural Information Specialist (2005 – 2010), and has spent over 15 years working with various international development organizations, including the World Bank, in the field of agricultural information. *Information Development* is a peer-reviewed journal, and the references cited by the article include a mixture of peer-reviewed articles and government sources. Ballantyne approaches the subject with a demonstrably wide range of knowledge about using ICT for the expansion of food security and agricultural development.

Summary. Ballantyne states that the ability to both share and take advantage of new knowledge is as important as the ability to generate new knowledge, and that the use of

ICTs is vital to that process. Ballantyne advocates for an innovation system perspective that “focuses on interactions among different actors working to bring change” (p. 261). One of the key actors in the innovation system is the local farmer, and it is vital that the famer has the means and ability to document her or her experiences and knowledge. It will be increasingly vital that information and communication specialists are utilized to work with the farmers and other stakeholders in agricultural information to ensure that the knowledge is shared and utilized.

Ballantyne further states that ICT must link the farmers to each other and to the markets directly, as well as to researchers and government services. This will ensure that farmers are able to define their own needs. There are four necessary features to guarantee a successful system: (a) the output needs to be available, “explicit and documented and described” (p. 265); (b) the output needs to be accessible and easy to find; (c) the output needs to be openly accessible – “licensed using Creative Commons or equivalent” (p. 266), and (d) the output needs to be appropriable or applicable, relevant, and customizable.

Chowdhury, N. (2001). *Information and communications technologies*. (Appropriate technology for sustainable food security). Retrieved from the International Food Policy Research Institute website http://www.ifpri.org/sites/default/files/publications/focus07.pdf

Abstract. Nuimuddin Chowdhury explores how ICT can improve the economic welfare of the rural poor. He stresses the opportunities offered by Internet connectivity and cell phones and argues that filling the existing strong latent demand for more information in rural areas could greatly benefit the poor. He calls on policymakers to create policies and institutions that will foster rapid spread of ICT infrastructure in rural areas.

Credibility. Nuimuddin Chowdhury studied economics at both Punjab University in Lahore, Pakistan and at the University of Cambridge in England. At the time of publication, he was employed at the International Food Policy Research Institute, and has since worked for the Bangladesh Institute of Development Studies (BIDS) and the World Bank. He currently runs Grameen Software Limited. This article is one of several policy briefs published in “A 2020 Vision for Food, Agriculture, and the Environment,” by the International Food Policy Research Institute (IFPRI). IFPRI is one of the 15 centers supported by the Consultative Group on International Agricultural Research (CGIAR), and its mission is to provide policy solutions that reduce poverty and end hunger and malnutrition.

Summary. Chowdhury discusses the importance of a robust ICT infrastructure in rural development and food security. He states that the use of the Internet, the World Wide Web, and wireless phones in rural areas can improve not only the connectivity of small agricultural producers (such as farmers and fisherpersons), but can also improve the “business processes that create and mobilize robust supply chains” (p. 12).

Chowdhury lists six policies that would bring the benefit of ICT to small agricultural producers: (a) invest in rural telecommunications and ICT infrastructure; (b) invest in telecommunications companies “to the point of making them economically viable commodities” (p. 13); (c) enable farmers to connect to the Internet and create communications networks to link farmers together; (d) ensure that market information is readily available to food producers; (e) provide appropriate hardware and software to farmers; and (f) ensure that rural schools are connected to the Internet, have the appropriate hardware and software, and that the children are learning to create, access, and utilize the available knowledge.

Gareau, S. E. (2004). The development of guidelines for implementing information technology to promote food security. *Agriculture and Human Values*, *21*(4), 273-285.

Abstract. Food insecurity, and its extreme form, hunger, occurs whenever the accessibility to an adequate supply of nutritional and safe foods becomes restricted or unpredictable. A potential tool in the fight against food insecurity and hunger is information technology (IT), since its use and range of application continue to grow at astonishing rates. The study examined the question of how information technology, particularly the Internet, can be used to promote food security. The results of this research show that appropriate, Internet-based, IT holds promise for the reduction of certain social problems, such as food insecurity and hunger.

Credibility. Stephen E. Gareau has a PhD in Instructional Technology and an MSc in Agricultural and Biosystems Engineering. At the time of publication, Gareau was Assistant Professor of Instructional Technology at McNeese State University in Lake Charles, LA. He is currently Associate Professor in the Department of Computer Information Systems at Buffalo State University and has published over 22 articles on technology. *Agriculture and Human Values* is a peer-reviewed journal, and the references cited in the article include a mixture of peer-reviewed articles, websites, and publications about modern information and communication technologies, and government sources.

Summary. This article cites several statistics about and causes of food insecurity. Gareau states that a “lack of appropriate technology can also contribute to food insecurity” (p. 274) via lack of communication, knowledge sharing, coordination of efforts, and networking. The article lists nine food security system needs that are related to technology and how IT could meet those needs. Table 2 presents a few examples of the needs and potential IT solutions.

Table 2

Food security needs and technology solutions (p. 280)

Food Security Need	**Potential IT Solution**
Improved public knowledge of available services	Web sites with relevant information
Communication and coordination between food assistance organizations	Email or listserv system among organizations
Improved referral information	Web-based food inventory database for each organization

Gareau concludes that IT, “particularly database and Internet technologies…can be applied to many of the information, communication, and coordination needs of food assistance organizations…to promote community food security” (p. 283).

Ingram, J. (2011). A food systems approach to researching food security and its interactions with global environmental change. *Food Security*, 3(4), 417-431, doi: 10.1007/s12571-011-0149-9

Abstract. There is growing concern that satisfying societal demand for food over coming decades will be increasingly challenging. This paper lays out a case for a food systems approach to research the complex food security/GEC arena and provides a number of examples of how this can help. These include (i) providing a framework for structuring dialogues aimed at enhancing food security and identifying the range of actors and other interested parties who should be involved; (ii) integrating analyses of the full set of food system activities (i.e. producing, storing, processing, packaging, trading and consuming food) with those of the food security outcomes i.e. stability of food access, utilisation and availability, and all their nine elements (rather than only food production); (iii) helping to

both assess the impacts of GEC on food systems and identify feedbacks to the earth system from food system activities; (iv) helping to identify intervention points for enhancing food security and analysing synergies and trade-offs between food security, ecosystem services and social welfare outcomes of different adaptation pathways; and (v) highlighting where new research is needed.

Credibility. John Ingram has an MSc in soil chemistry, a PhD from Wageningen University (his thesis was titled "*From food production to food security: Developing interdisciplinary, regional-level research*"), and over 20 years of experience working on international agriculture and agroecology projects. Ingram is the Natural Environment Research Council (NERC) Food Security Leader and has over 11 first author publications on the subject of food security and environment. *Food Security* is a peer-reviewed journal, and the references cited by the article include a mixture of peer-reviewed articles and government sources.

Summary. This article states that food insecurity is not necessarily a result of the lack of sufficient food production, but rather a lack of access to food by all people. One of the three major challenges identified for agronomists in the quest to increase food security is to "to understand how best to address the information needs…and communicate agronomic research results in a manner that will assist the development of food systems" (p. 419). Ingram states that ICT can positively impact food security outcomes in several key areas: (a) food production (particularly via Internet access to aid communication between producers), (b) food distribution (by using ICT to enable Internet ordering and GIS for better forecasting), (c) food affordability (by using web connectivity to inform consumers and GIS to reduce production costs), (d) food exchange (via cell phone technology to aid producers in finding the best local markets and e-commerce to increase and encourage trade and data exchange), and (e) food safety (through smart packaging, food monitoring, and food tracking and traceability.

Kamssu, A., Siekpe, J., Ellzy, J, & Kamssu, A. (2004). Shortcomings to globalization: Using Internet technology and electronic commerce in developing countries. *The Journal of Developing Areas*, *38*(1), 151-169.

Abstract. Information and communications technology (ICT) has become an indispensable tool in the fight against world poverty. ICT provides developing nations with an unprecedented opportunity to meet vital development goals, such as poverty reduction, basic healthcare, and education, far more effectively than before (UNDP, 2000). The present study investigates the impact of information technology (IT) infrastructure, ISPs, and socio-economic factors on ICT access and use. Statistical analyses show that there is an empirical relationship between these factors and the Internet adoption in different countries; which may help explain the gaps between groups with respect to Internet use.

Credibility. Aurore Kamssu and Jeffrey Siekpe each have PhDs in Management Information Systems and are Associate Professors of Business Information Systems at Tennessee State University. James Ellzy has an EdD and is Professor and Chair of the Business Information Systems Department at Tennessee State University. *The Journal of Developing Areas* is a peer-reviewed journal, and the references cited by the article include several peer-reviewed articles.

Summary. This article states the ICT is “an indispensable tool in the fight against world poverty” (p. 151). Having reliable Internet access and affordable IT equipment and telecommunication services is crucial for the spread of e-commerce and rural development. Infrastructure development and government support (both local and federal) are necessary to increase access to the Internet and appropriate telecommunication services, but hardware is also a crucial piece of the rural development puzzle. If these pieces are put into place, the rural areas will be able to connect to the Internet and participate in the growing communication and e-commerce communities both locally and worldwide, thus aiding in the fight against poverty.

Larsen, R. K., Powell, S. Sriskandarajah, N., Peterson, T. (2010). Towards a learning model of ICT application for development: Lessons from a networked dialogue in Sweden. *Information, Communication & Society, 13*(1), 136-150.

Abstract. This paper reports on a two-day workshop held in Sweden (7-8 April 2008) to bring together researchers and professionals to share insights and experiences in the application of information and communication technology (ICT) to sustainable development (SD). The focal point of the workshop was the conjunction of ICTs, environment, and development. A systemic learning model is outlined as a means to enable more effective use of ICTs by balancing technical knowledge with insights into the context and history of the stakeholders and their field of application.

Credibility. At the time of publication, all authors were associated with the Swedish University of Agricultural Sciences. Currently, Rasmus K. Larsen has an MSc from the School of Geography and the Environment at Oxford University and an MSc from the Institute of Biology at Copenhagen University. He is currently a PhD student with the Communication and Innovation Studies Group at Wageningen University in the Netherlands and is a Research Associate in the natural resource management and international development at Wageningen University. Stina Powell has an MA in Cultural Anthropology and Development Studies and is a Research Associate at Research Officer in the Division of Environmental Communication at the Swedish University of Agricultural Sciences. Nadarajah Sriskandarajah, PhD is Professor and Chair of Environmental Communication in the Department of Urban and Rural Development at the Swedish University of Agricultural Sciences. Tarla Rai Peterson has a PhD from Washington State University and is Professor and Boone and Crockett Chair in the Department of Wildlife and Fisheries Sciences at Texas A&M University. *Information, Communication & Society* is a peer-reviewed journal. The majority of references cited are articles from peer-reviewed journals, conference proceedings and workshop reports, and books.

Summary. This article discusses the role of ICT in rural poverty alleviation and related areas such as health and food security. Larsen et al. stress the need for cooperation between local governments, non-governmental organizations, and other stakeholders to increase access to ICT in rural areas. The main obstacle to the use of ICT to improve information and knowledge management in rural areas is lack of infrastructure, usually related to remote locations and economic barriers. However, if that obstacle can be breached, ICT has the ability to increase rural development and alleviate poverty by enabling information and knowledge sharing between farmers in various remote locations, urban experts, and policy makers. Mobile phones are the easiest technology to deploy to remote areas due to the lack of additional infrastructure needs, and can immediately increase communication between individuals and other stakeholders in rural development and food security. However, they are less capable of expanding into a widespread knowledge sharing tool, so Internet connectivity also needs to be considered a vital piece of ICT in rural development. The authors caution that access – both geographic and economic - must be considered when planning ICT development in rural areas so that the very people meant to be reached are not inadvertently left out.

Lashgarara, F., Mirdamadi, S. M., & Hosseini, S. J. F. (2011). Identification of appropriate tools of information and communication technologies (ICT) in the improvement of food security of Iran's rural households. *African Journal of Biotechnology*, *10*(45), 9082-9088.

Abstract. Access to sufficient and desirable food is one of the principles of any developing and healthy society. One of the important means for attainment of food security is information and communication technologies (ICT). The purpose of the research was to identify appropriate tools of ICT in improving food security of Iran's rural households. ICT can improve food security of rural households.

Credibility. Farhad Lashgarara has a PhD in Agricultural Extension and is Assistant Professor in the Department of Agricultural Extension and Education at the Islamic Azad University in Tehran, Iran. The other authors were, at the time of publication, all associated with Islamic Azad University in Tehran, Iran. *African Journal of Biotechnology* is a peer-reviewed journal and the references cited by this article are a combination of articles from peer-reviewed journals, government reports, and reports from non-governmental organizations. There are a few grammatical errors that are likely related to either translational issues or English not being the first language of the author.

Summary. This article discussed the positive correlation between ICT and rural development. The authors found that the acquisition of knowledge via electronic diffusion has improved both financial decision and food production. Lashgarara et al.

look at various forms of ICT including (a) new technologies (e.g. Internet, mobile phones, web conferencing), (b) old technologies (e.g. radio, phone, and television), and (c) very old methods of communication (e.g. workshops, printed materials, and conferences) and have determined that all ways of communicating have a positive effect on information diffusion, and thus food security. Electronic sources, i.e. the new technologies, are the most important resource for food security improvement. However, the authors also found that utilization of any of the information and communication methods not only improve “the ability of individuals to acquire information” (p. 9087), but in rural households that do not always have access to the newer technologies, it is essential that older methods of communication be considered as valuable.

Lashgarara, F., Mirdamadi, S, Hosseini, S., & Chizari, M. (2008). The role of food-security solutions in the protection of natural resources and environment of developing countries. *Environmental Challenges in the Pacific Basin, 1140,* 68-72.

Abstract. One of the main millennium development goals (MDGs) is protection of the environment and people's health. This cannot be obtained unless there is ensured food security. At the same time, with ensured food security, we can hope to protect the natural resources and environment. Some of the most important food-security solutions that can play an important role in this relation are discussed, including conventional research-based technology, biotechnology, information and communication technologies (ICTs), alternative energy sources, and food irradiation.

Credibility. Farhad Lashgarara has a PhD in Agricultural Extension and is Assistant Professor in the Department of Agricultural Extension and Education at the Islamic Azad University in Tehran, Iran. The other authors were, at the time of publication, all associated with Islamic Azad University in Tehran, Iran. *Environmental Challenges in the Pacific Basin* is a collection of peer-reviewed articles published in the Annals of the New York Academy of Science. The references cited by this article are mostly from the International Food Policy Research Institute, one of the 15 centers supported by the Consultative Group on International Agricultural Research (CGIAR) whose mission is to provide policy solutions that reduce poverty and end hunger and malnutrition.

Summary. This article describes three dimensions of food security: (a) food availability, (b) food accessibility, and (c) food utilization. Several policies are suggested that will positively affect these dimensions. The first proposed policies are to invest in local ICT infrastructure for rural areas, and then to ensure that farmers have the correct tools to access the ICT infrastructure. It is considered crucial that local farmers are able to connect with each other and access market data to stay updated with market trends, new technologies, and supply and demand. The authors suggest that by implementing these policies, small farmers will be more competitive and will be able to enter the "information-driven" (p. 70) marketplace. In addition, these policies will provide small famers with up-to-date information about food and agricultural markets, improve business profitability, and "foster the diversification of the rural economy" (p. 70), all of which will have a beneficial impact on both food availability and food accessibility.

McLaren, C., Metz, T., Berg, M, Bruskiewich, R., Magor, N., et al. (2009). Informatics in agricultural research for development. *Advances in Agronomy*, *102*, 135-157.

Abstract. Technical developments in information and telecommunications technology (ICT)… are providing an environment where scientists from developed and developing countries can collaborate to address real problems of food security and development.

Aspects of this enabling technology are improved connectivity between developed and developing countries, availability of open-source applications that are both cheap and amenable to innovative local adaptation and the emergence of global software and platform services that lower the infrastructure barriers to accessing state-of-the-art computer applications. ICT also has a role to play in the "last mile" problem of disseminating information to farmers. Innovative strategies for combining Internet, telecommunications, video, and print technologies at appropriate levels are bridging this gap and empowering farmers to make better production and marketing decisions.

Credibility. All authors were associated with the International Rice Research Institute (IRRI) at the time of publication. C. Graham McLaren has an MSc and PhD in Mathematical Statistics from Simon Fraser University, Canada and is currently the leader of the Bioinformatics and Crop Information sub-program at the Generation Challenge Program (GCP). Thomas Metz is a Senior Scientist in Research Informatics at IRRI. Marco van den Berg has a PhD in genetic and physiological studies and is currently Principal Scientist in Applied Biochemistry and Screening for DSM Food Specialties. Richard M. Bruskiewich has a PhD in Medical Genetics from the University of British Columbia and is a Bioinformatics Specialist at IRRI. Noel P. Magor has a PhD in Politics from the University of Adelaide and a MAgr in Tropical Agronomy from Sydney University. Magor is currently the Head of the Training Center and Manager of the Rice Knowledge Bank at the IRRI. David Shires is acting head of the *IRRI* Training Center. This article is published in *Advances in Agronomy*, a peer-reviewed journal. The references cited are a mixture of peer-reviewed articles, government and non-governmental organization sources, and agriculture websites.

Summary. This article states that two of the major barriers to the spread of ICT are (a) infrastructural constraints and (b) the lack of open-source and open content software. The wide availability of information and communication technologies, including Internet and mobile phones, will enable farmers to access more crop information and stay abreast of current trends and new technologies in agriculture, as well as being able to respond in a timely fashion to changes in demand. Better infrastructure and greater access to ICT will initiate a closer connection between the farmer and farmer intermediaries, creating an innovation system for knowledge and information sharing which can positively influence food supply at both the farm and local market levels.

Yaghoobi, N. & Sarani, A. H. (2011). Effective factors on efficient development of rural ICT centers. *European Journal of Social Sciences, 25*(3), 443-455.

Abstract. This article describes research that investigates effective factors of development of rural ICT services. The research was primarily collected through researcher-made questionnaires and analyzed to identify the effective factors on the development of services of rural ICT.

Credibility. Noor-Mohammad Yaghoobi, PhD and Abdol Hamid Sarani, PhD are both faculty members at the Zahedan Branch of Islamic Azad University in Zahedan Iran. Dr. Yaghoobi is the Research Sub-Dean of Management and Accounting. The *European Journal of Social Sciences* is an international peer-reviewed journal. The majority of sources cited by this article are books, although there are articles from peer-reviewed journals and reports published by both governmental and non-governmental organizations. The few spelling and grammar errors in the article appear to be the result of English as a second language.

Summary. This article states that "knowledge and information are the main elements of food security and that they are essential for facilitating rural divilopment [sic] and creating economic and social changes" (p. 444). The authors assert that the confluence of communication technologies, information processing technologies, and transferring technologies lead to a more interactive world, and thus improve communication, knowledge sharing, and information management at the local food level. Improved access to ICT and decreased costs make information exchanges nearly instantaneous. This improved access allows farmers and local agents to more easily exchange information, make adjustments as new information becomes available, and incorporate innovations more quickly. When coupled with newer mapping technologies such as GIS, farmers and local merchants can better forecast crop production, supply, and marketing strategies.

Theme 2: Geographic Information Systems and Production and Distribution of Food

Charreire, H., Casey, R., Salze, P., Simon, C., Chaix, B., et al. (2010). Measuring the food environment using geographical information systems: A methodological review. *Public Health Nutrition*, *13*(11), 1773-1785.

Abstract. This literature review investigated the geographic information systems (GIS) methods used to define the food environment and the types of spatial measurements they generate. Two different spatial approaches were identified. The density approach quantifies the availability of food outlets using the buffer method, kernel density estimation or spatial clustering. The proximity approach assesses the distance to food outlets by measuring distances or travel times. GIS network analysis tools enable the modeling of travel time between referent addresses (home) and food outlets for a given transportation network and mode, and the assumption of travel routing behaviors. GIS methods provide new approaches for assessing the food environment by modeling spatial accessibility to food outlets.

Credibility. Hélène Charreire is a lecturer at the French Institute of Urban Planning in the Geography Department and is associated with University Paris. Jean-Michel Oppert is Professor of Nutrition at Pierre-et-Marie Curie (Paris VI, Pitié-Salpêtrière Medical School) and has a clinical practice at the Department of Nutrition, Hôtel-Dieu Hospital, Paris. He has an MD with a specialization in endocrinology and a PhD in Human Nutrition. The remaining authors are with the Human Nutrition Research Center at the University of Lyon (Casey and Simon), The University Strasbourg (Salze, Banos, Badariotti, and Weber), and the French National Institute of Health and Medical Research in Paris (Chaix). *Public Health Nutrition* is a peer-reviewed journal and the majority of the 84 sources cited are from peer-reviewed journals.

Summary. This article discusses the importance of spatial accessibility as it applies to food security, and specifically looks at different methods to assess said accessibility. Charreire et al. look at GIS methods of mapping to determine the locations of food outlets and spatial analysis to identify inequalities in access. Charreire et al. look specifically at two methods of measuring access to food outlets: (a) density of food outlets and (b) proximity of the population to said outlets. The authors find that GIS mapping provides an important advantage in these assessments and allow urban planners and policy makers visualize urban access to food without being limited by pre-defined residential zones. The authors' intentions are to "influence policies and incite urban planners to modify the food environment accordingly" (p. 1774). The authors believe that as GIS analysis becomes more advanced and more readily available, this mapping tool will become increasingly useful in the fight against food insecurity.

Deichmann, U. & Wood, S. (2001). *GIS, GPS, and remote sensing.* (Appropriate technology for sustainable food security). Retrieved from the International Food Policy Research Institute website http://www.ifpri.org/sites/default/files/publications/focus07.pdf

Abstract. Uwe Deichmann and Stanley Wood focus on whether geographical information technologies, such as global positioning systems, are appropriate tools for the poor in developing countries. They find that information generated by these technologies is used widely in developing countries to track land use and land degradation, human settlement, and many other uses. However, the benefits for the rural poor have been mostly indirect, through better information. The authors conclude that geographical information technology offers great opportunities for improving rural livelihood through better information.

Credibility. Uwe Deichmann has a PhD in Geography from the University of California at Santa Barbara, and at the time of publication worked for the International Food Policy Research Institute (IFPRI). He is currently the Senior Environmental Specialist in the Development Research Group and coordinator of its Spatial Analysis Team at the World Bank. Stanley Wood earned his MSc in Water Resources Development from the University of Birmingham and an MSc in Agricultural Development and PhD in Economics from the University of London. Wood is a Senior Research Fellow at IFPRI. This article is one of several policy briefs published in “A 2020 Vision for Food, Agriculture, and the Environment” by IFPRI. IFPRI is one of the 15 centers supported by the Consultative Group on International Agricultural Research (CGIAR), and its mission is to provide policy solutions that reduce poverty and end hunger and malnutrition.

Summary. This article discusses the importance of GIS and GPS in rural development, particularly as it relates to agriculture and food security. Deichmann and Wood state that GIS and spatial technology improve information gathering and sharing through web mapping and spatial inventories. This increased information about agroecology and socioeconomic conditions aid government and private institutions in “planning rural infrastructures” and “improve targeting interventions to the poorest communities” (p. 15). The article mentions that the primary benefit of GIS mapping is the ability to share information and knowledge about food supply and demand, emergency planning and response, and the dissemination of agriculture-related information such as market prices and weather forecasts as well as to link area farmers together to share information and pool resources.

Eckert, J., & Shetty, S. (2011). Food systems, planning and quantifying access: Using GIS to plan for food retail. *Applied Geography*, *31*(4), 1216-1223. doi:10.1016/j.apgeog.2011.01.011

Abstract. Local food systems are often overlooked by urban planners, as the prevailing belief is that the private market is responsible for delivery of this system. This paper seeks to quantify and map accessibility of the food system in Toledo, Ohio, using geographic information science to measure the accessibility of each block group to retailers selling a selection of fresh foods to determine whether spatial accessibility to food outlets carrying nutritious and healthy choices is a concern in Toledo. This information can guide the discussion of local food systems planning and identify neighborhoods that could have significant numbers of residents facing food accessibility challenges.

Credibility. Jeanette Eckert has an MA in Geography and is currently a Research Assistant and the Survey Research Services Manager for the Urban Affairs Center at the University of Toledo in Toledo, OH. Sujata Shetty has a MS and PhD in Urban Planning from the University of Michigan and is Associate Professor in the Department of Geography and Planning at the University of Toledo. *Applied Geography* is a peer-reviewed journal and over half of the articles cited by Eckert and Shetty are peer-reviewed.

Summary. This article primarily focuses on food insecurity in urban areas and discusses how GIS can be used to improve security in those areas. Eckert and Shetty point out that the main barrier to food security in urban settings is access – both economic and geographic. They propose that GIS mapping be used to determine where food deserts exists in urban areas and that information be utilized by urban planners to improve geographic access to food. They also suggest that urban planners use the GIS maps to plan for urban agriculture, such as community gardens.

The authors conclude that community food security can be addressed through careful planning and the use of GIS mapping. It is important that this information be made available, not only to urban planners, but also to "community activists, public health officials, and others concerned with equitable access to food" (p. 1219).

Gregory, P. J., Ingram, J. S., & Brklacich, M. (2005). Climate change and food security. *Philosophical Transactions B, 360*. 2139–2148. doi:10.1098/rstb.2005.1745

Abstract. Dynamic interactions between and within the biogeophysical and human environments lead to the production, processing, distribution, preparation and consumption of food, resulting in food systems that underpin food security. Food systems encompass food availability (production, distribution and exchange), food access (affordability, allocation and preference) and food utilization (nutritional and societal values and safety), so that food security is, therefore, diminished when food systems are stressed. Because of the multiple socio-economic and bio-physical factors affecting food systems and hence food security, the capacity to adapt food systems to reduce their vulnerability to change is not uniform. Improved systems of food production, food distribution, and economic access may all contribute to food systems adapted to cope with climate change, but in adopting such changes, it will be important to ensure that they contribute to sustainability.

Credibility. Peter Gregory, PhD is Professor of Global Food Security at the University of Reading. John Ingram has an MSc in soil chemistry, a PhD from Wageningen University. Ingram is the Natural Environment Research Council (NERC) Food Security Leader and has over 11 first author publications on the subject of food security and environment. Michael Brklacich has a PhD in Geography from the University of Waterloo and is Professor and Chair of the Department of Geography and Environmental Studies at Carleton University in Ottawa, Ontario, Canada. *Philosophical Transactions B* is a peer-reviewed journal devoted to the Biological Sciences published by The Royal Society. The majority of sources cited by this article are published in peer-reviewed journals.

Summary. This article discusses the links between local food systems, food production, and food security. Because food production and geographical food access are not direct corollaries, a measurement of food production does not necessarily answer questions about food security. In addition to availability of food, geographical and socioeconomic access is vital to maintaining regional food security. Food systems can have a variety of complexities, but in its simplest form, a food system would consist of a person who "produces, processes and consumes food on [a] farm" (p. 2141). However, in the modern world, that type of food system is much less common, and the systems have been integrated with global markets. Globalization of food systems has a profound effect on production, distribution, and economic and geographic access. Adapting food systems to the modern realities of globalization can help regulate production and distribution, and if socioeconomic factors are included in food system mapping and development, food security can be protected as well.

Hwang, M. & Smith, M. (2010). Integrating publicly available web mapping tools for cartographic visualization of community food insecurity: A prototype. *GeoJournal, 0343*(2521), 1-16. doi: 10.1007/s10708-010-9385-3

Abstract. Spatial profiling of community food security data can help the targeting of geographic areas and populations most vulnerable to food insecurity. [T]his study presents a web mapping framework that integrates a variety of publicly available software tools to enable spatial exploration of both quantitative and qualitative data. Specifically, our framework allows online choropleth (thematic) mapping and thematic data exploration through a mixture of free mapping Application Programming Interfaces (APIs) and open source software tools for spatial data processing and desktop-like user interfaces. This suggests that web-based cartographic visualization using publicly available software tools can be useful for spatial examination of community food insecurity as well as for cost-effective distribution of the resulting map information.

Credibility. At the time of publication, both Myunghwa Hwang and Marissa Smith were PhD students in the GeoDa Center for Geospatial Analysis and Computation, School of Geographical Sciences and Urban Planning at Arizona State University in Tempe, AZ. Smith has since earned her PhD in Geography and is currently a Foreign Services Officer for the State Department and Hwang is a graduate student at Arizona State University. Hwang has a BA and MA in Geography, both from Seoul National University in Seoul, South Korea. *GeoJournal* is a peer-reviewed journal, and the references used in this article are an almost even mix of peer-reviewed articles and government sources.

Summary. Hwang and Smith state that one key component of improving food security is ensuring geographic access to food. In order to improve geographic access, they propose increasing spatial profiling through the use of geographic information systems and mapping to understand "substantial geographic differences in poverty and food security within and between communities" (p. 2). The development and use of open access web mapping tools is critical to the success of comprehensive mapping in areas that do not have the financial resources to invest in expensive mapping software systems.

This article states that community food security (CFS) can be addressed by linking food security data with online mapping systems. Two issues need to be addressed while making online food security maps available: (a) easy and affordable access to said maps, including a user-friendly updating system and (b) flexible dissemination strategies that encourage collaboration and communication among all stakeholders. Due to a recent increase in the availability of open source GIS and mapping software, access to maps is becoming easier and more affordable. Hwang and Smith recommend that online food security maps contain three types of content: (a) food supplier locations; (b) demographic, land use, and other census-type data; and (c) relevant food security issue records.

McEntee, J., & Agyeman, J. (2010). Towards the development of a GIS method for identifying rural food deserts: Geographic access in Vermont, USA. *Applied Geography*, *30*(1), 165–176. doi:10.1016/j.apgeog.2009.05.004.

Abstract. The food desert metaphor has been widely used by academics and politicians alike. While there is general agreement on what a food desert is in a relatively vague sense, strategies to identify food deserts, especially in a rural setting, using a systematic method remain undefined. The purpose of this paper is to contribute towards the development of a method for rural food desert identification strategies using the location

of food retailers and residential units. We apply a methodologically innovative GIS approach to the primarily rural state of Vermont, USA. Areas of inadequate geographic food access are identified and some are found to overlap with high poverty locations. Aims for future work are identified including fieldwork to validate these findings.

Credibility. At the time of publication, Jesse McEntee was a PhD candidate at Cardiff University. In 2011, he received his PhD from Cardiff University's School of City and Regional Planning with a dissertation on “Shifting Rural Food Geographies and the Spatial Dialectics of Just Sustainability.” Julian Agyeman has a PhD in Environmental Education from the University of London and is Professor and Chair of the Department of Urban + Environmental Policy + Planning (UEP) at Tufts University. *Applied Geography* is a peer-reviewed journal, and the majority of sources cited in the article appear in peer-reviewed journals.

Summary. This article examines the relationship between rural food security and food availability by identifying food deserts through the use of GIS. GIS is used to not only enable mapping, but also as a tool for spatial and statistical analysis. It goes beyond traditional mapping by illustrating travel times via single-family vehicles (personal cars or trucks) and public transportation options. This paper specifically looks at geographic food access (as opposed to economic or informational food access) by measuring the distance between food markets in rural areas. The methods developed by McEntee and Agyeman can be easily transferrable to most regions in the United States, since all states have GIS data available with road networks. The results of the implementation of the GIS mapping to find food deserts could inform urban and rural planners in determining where to locate food pantries or other food aid outlets, supermarkets, and where food insecurity might be a hidden issue.

Ostry, A. & Morrison, K. (2009). Developing and utilizing a database for mapping the temporal and spatial variation in the availability of "local foods" in British Columbia. *Environments: A Journal of Interdisciplinary Studies, 36*(1). Retrieved from http://www.environmentsjournal.ca/index.php/ejis/article/view/9701/6648

Abstract. In response to growing concerns regarding food security, nutrition-related health problems, and environmental degradation, the marketing of "local foods" has gained popularity. However, before policy makers can promote local food security, they need knowledge of the local geography of food resources. In particular, they must know, within fairly small geographic areas, what foods are produced, under what financial and agricultural conditions, and in what quantities. In this paper we describe the development of a unique database used to frame a conceptual model for better determining local food resources using GIS and Census data. In order to reduce food miles, improve local food security, and address calls from health experts for higher fruit and vegetable consumption, it is essential that policy makers have basic information on agricultural and food production available for planning.

Credibility. Aleck Ostry has Masters Degrees in History and Health Services Planning and a PhD in Epidemiology. He is Associate Professor in the Faculty of Social Sciences at the University of Victoria, holds a Canada Research Chair in the Social Determinants of Community Health, is a Senior Scholar with the Michael Smith Foundation for Health Research, and has published widely in the fields of public health and food security. Kathryn Morrison has an MSc in Spatial Analysis, and at the time of publication was a

Research Assistant in Ostry's lab. She is currently finishing her PhD in Epidemiology in the Surveillance Laboratory within the Clinical and Health Informatics Unit at McGill University in Montreal, Quebec. *Environments: A Journal of Interdisciplinary Studies* is peer-reviewed and the references cited are equally divided between peer-reviewed articles and government sources.

Summary. This paper suggests that the development of a geospatial database is "essential to move research on sustainable local food security ahead" (p. 21). Ostry and Morrison put forward that the information gathered and mapped in the geospatial databases would improve knowledge about food production and distribution for both farmers and local food systems. This knowledge would improve targeted food production and distribution.

An open source, publicly available database and map of the geospatial data gathered has the potential to be used by local and state governments, and could be contributed to by farmers, educators, and community activists. It would also enable consumers to know "what food is produced locally, under what conditions, and where the local produce enters the marketplace" (p. 30).

Pothukuchi, K. (2004). Community food assessment - a first step in planning for community food security. *Journal of Planning Education and Research, 23*(4), 356-377.

Abstract. Community food assessments (CFAs) constitute a first step in planning for community food security. Community food security is a situation in which all community residents obtain a safe, culturally acceptable, nutritionally adequate diet, through a sustainable food system that also maximizes community self-reliance and social justice. This article discusses their common threads to planning, how a planning approach might strengthen CFAs. CFAs employed spatial mapping techniques to analyze a variety of issues, explored more and diverse community food linkages, used multiple sources and methods, envisioned a key role for community planning agencies, distributed their findings widely, and helped place planners in leadership positions.

Credibility. Kameshwari Pothukuchi, PhD is Associate Professor of Geography and Urban Planning in the College of Liberal Arts & Science at Wayne State University in Michigan. The *Journal of Planning Education and Research* is a peer-reviewed quarterly and a majority of the sources cited by Pothukuchi are found in peer-reviewed journals, although several come from government (both state and federal) and university sources.

Summary. This article addresses the ways that Community Food Assessments can be used to positively affect community food security. The focus is on building partnerships between stakeholders to enhance the gathering, sorting, and dissemination of information and knowledge. Pothukuchi states that there are five key functions that play an important role in building community food security: (a) central intelligence "to facilitate local operations of different food system functions," (b) pulse-taking "to alert the community…to danger signs…that may impact food access," (c) policy clarification "to help frame and regularly revise food system functions," (d) community food security strategic plan "to phase specific private and public programs toward enhancing community food security," and (e) feedback review "to analyze…the consequences of program and project activities" (p. 360). Pothukuchi also discusses the ways that GIS can be used to map food resources and population groups. This information is used in urban planning to "suggest locations for resources and programs" (p. 370) and to help aid agencies determine where food deserts exist and where services are greatly needed.

Russell, S. E. & Heidkamp, C. P. (2011). Food desertification: The loss of a major supermarket in New Haven, Connecticut. *Applied Geography, 31.* 1197-1209. doi: 10.1016/j.apgeog.2011.01.010.

Abstract. In March of 2010, the only full-service supermarket centrally located in New Haven, Connecticut closed, stranding many of the city's residents in a food desert. A food desert is an urban or rural area with significantly limited access to retail sources of healthy and affordable food, due to a combination of socioeconomic disadvantages and physical distance. This article considers the pivotal and causative role of the business model of supermarkets in the creation of new or exacerbation of current urban food deserts, as well as in the impact the loss of one market has on the resilience of the community's food system. Using the events of New Haven as a case study, the form and severity of the food desert in New Haven is analyzed by mapping ¼ mile, ½ mile, and 1 mile road network service areas of the major supermarkets and grocery stores of the area. These are compared against U. S. Census block group data of the New Haven population's median household income, poverty level, and access to a personal vehicle. The results show certain parts of the city with low income, high poverty, and low vehicle access to exist in hardship outside the service areas of nearby stores. GIS methodology aids in illustrating the conclusion that the loss of just one supermarket has had significantly detrimental effects on the geographical food access of the city's residents. The ongoing lack of a full-service supermarket in the city not only raises concerns about the value of a new supermarket coming in, but also creates possibilities for seeking alternative food system solutions.

Credibility. Scott Russell has a BS in Geography from Southern Connecticut State University and is a Master's student in the Department of Geography at the University of Connecticut, Storrs, CT. C. Patrick Heidkamp has a PhD in Geography and is Assistant Professor in the Geography Department at the University of Connecticut. *Applied Geography* is a peer-reviewed journal, and the majority of sources cited by this article appear in peer-review journals.

Summary. Although this article is a case study on a specific food desert in Connecticut, the methods and conclusions reached by the authors have wider applicability. An urban food desert can affect food security in a wide radius, especially for people under the poverty line who do not have access to multiple forms of transportation. GIS is being used more frequently to provide visual proof of urban food deserts, and the resulting spatial analysis informs urban planners and policy makers regarding geographic food access in urban areas. The overlay of GIS data with socioeconomic information can highlight food desert areas that would otherwise remain invisible. By using GIS map layers with roads, census information, and town boundaries, urban planners and local government officials can choose various distances to determine which socioeconomic classes have adequate access to food sources.

Wu, W., Tang, H., Yang, P., You, L., Zhou, Q., et al. (2011). Scenario-based assessment of future food security. *Journal of Geographical Sciences, 21*(1), 3-17.

Abstract. This paper presents a scenario-based assessment of global future food security. To do that, the socio-economic and climate change scenarios were defined for the future and were linked to an integrated modeling framework. The crop yields simulated by the GIS-based Environmental Policy Integrated Climate (EPIC) model and crop areas simulated by the crop choice decision model were combined to calculate the total food production and per capita food availability, which was used to represent the status of food availability and stability. Low food production associated with poverty is the determining factor to starvation, and more efforts are needed to combat hunger in terms of future actions.

Credibility. Wenbin Wu has a PhD in "global-scale modeling of agricultural land-use change by linking biophysical and socio-economic aspects" from the University of Tokyo. Wu works in the key laboratory of Resources Remote Sensing and Digital Agriculture for the Ministry of Agriculture in Beijing, China as well as the Institute of Agricultural Resources and Regional Planning for the Chinese Academy of Agricultural Sciences. Huajun Tang is the Vice President for International Collaboration at The Chinese Academy of Agricultural Sciences in Beijing. He has an MS and PhD in Physical Land Resources from University of Ghent, Belgium. The other authors are associated with the Ministry of Agriculture (Yang, Zhou, Chen), the Chinese Academy of Agricultural Sciences (Yang, Zhou, Chen), the Center for Spatial Information Science at the University of Tokyo (Shibasaki), and the International Food Policy Research Institute (You). The *Journal of Geographical Sciences* is a peer-reviewed journal and the majority of sources cited are from peer-reviewed journals.

Summary. This article looks at the use of GIS to estimate future crop yields on a smaller scale to predict food insecurity. The use of socio-economic scenarios play very heavily into the GIS mapping and spatial analysis of this metric. The authors emphasize the importance of including demographic information, economic development, technology, and local food policies in all scenarios. In addition, GIS was used to ensure that road accessibility as well as agricultural technologies available were used. In addition, future population shifts were also taken into account so that food security would be based on both predicted crop yield and population. Based on the prediction models and the GIS mapping, the authors state that "it is possible to identify the future hotspots of food insecurity" (p. 14). Throughout the article, the authors argue that even more important than the production of adequate food sources, i.e. the *availability* of the food is the economic accessibility of food. Therefore, it is crucial to manage not just the supply, but also to ensure that the populations in question have adequate resources to obtain the necessary amounts of food to be considered food secure.

Wu, W., Yang, P., Tang, H., You, L., Zhou, Q., Chen, Z. & Shibasaki, R. (2011). Global-scale assessment of potential future risks of food insecurity. *Journal of Risk Research*, 14(9), 1143-1160. doi: 10.1080/13669877.2011.571794

Abstract. This paper presents an approach of combining biophysical, social, and economic factors for spatially explicit assessment of potential future risks of food insecurity. A GIS-based EPIC model was adopted to estimate the potential yields of different crop types and the potential risks of food insecurity were assessed.

Credibility. Wenbin Wu has a PhD in "global-scale modeling of agricultural land-use change by linking biophysical and socio-economic aspects" from the University of Tokyo. Wu works in the key laboratory of Resources Remote Sensing and Digital Agriculture for the Ministry of Agriculture in Beijing, China as well as the Institute of Agricultural Resources and Regional Planning for the Chinese Academy of Agricultural Sciences. Huajun Tang is the Vice President for International Collaboration at The Chinese Academy of Agricultural Sciences in Beijing. He has an MS and PhD in

Physical Land Resources from University of Ghent, Belgium. The other authors are associated with the Ministry of Agriculture (Yang, Zhou, Chen), the Chinese Academy of Agricultural Sciences (Yang, Zhou, Chen), the Center for Spatial Information Science at the University of Tokyo (Shibasaki), and the International Food Policy Research Institute (You). The *Journal of Risk Research* is a peer-reviewed journal and the majority of sources cited are from peer-reviewed journals.

Summary. This article proposes an approach to predict future food shortage and food security issues based on GIS-based models and spatial analysis. Specifically, a GIS-based Environmental Policy Integrated Climate (EPIC) model is used to measure potential crop outcomes based on climate change. In addition to crop assessments, the spatial analysis also considers population changes. The authors specifically look at both the food availability and the economic accessibility of food as measures of future food security. Wu et al. aim to inform policy decisions based on better predictors of future food security.

Theme 3: Food Safety and Security and Knowledge Management Systems

Altieri, M. A. (2002). Agroecology: The science of natural resource management for poor farmers in marginal environments. *Agriculture Ecosystems & Environment, 93.* 1-24.

Abstract. Throughout the developing world, resource-poor farmers (about 1.4 billion people) located in risk-prone, marginal environments, remain untouched by modern agricultural technology. A new approach to natural resource management must be developed so that new management systems can be tailored and adapted in a site-specific way to highly variable and diverse farm conditions typical of resource-poor farmers. Agroecology provides the scientific basis to address the production by a biodiverse agroecosystem able to sponsor its own functioning. The latest advances in agroecological research are reviewed in order to better define elements of a research agenda in natural resource management that is compatible with the needs and aspirations of peasants. Obviously, a relevant research agenda setting should involve the full participation of farmers with other institutions serving a facilitating role. The implementation of the agenda will also imply major institutional and policy changes.

Credibility. Miguel Altieri has a PhD in Entomology from the University of Florida. He is a Professor in the Department of Environmental Science, Policy, and Management at the University of California Berkeley. *Agriculture Ecosystems & Environment* is a peer-reviewed journal, and the majority of sources cited by this article appear in peer-reviewed journals.

Summary. This article discusses the necessity of using appropriate technologies and local agricultural knowledge to further food security through resource management and agroecology. Technology can be used to gather and disseminate knowledge from a variety of resources, including local farmers, regional experts, and policy makers. This pooling of knowledge can help create a new approach that takes into account both the ecosystem and the socioeconomic systems in areas with low food security. In order to successfully implement a natural resource management and innovative agroecological system, it will be vital to review and possibly improve local technological infrastructure. It will also be important to consider the local users when development knowledge bases and new agricultural innovations. The knowledge management systems will need to effectively link “farmers and external agencies… [to create] working partnerships” (p. 17). By utilizing local knowledge and new agroecological systems, farmers will achieve significant levels of both food security and resource conservation.

Brooks, S., & Loevinsohn, M. (2011). Shaping agricultural innovation systems responsive to food insecurity and climate change. *Natural Resources Forum*, *35*(3), 185-200.

Abstract. Recent global food crises have exposed the structural vulnerability of globalized agri-food systems, highlighting climate change as just one of a complex set of environmental, demographic, social and economic drivers generating instability and food insecurity, the impacts of which disproportionately affect poorer groups in marginal environments. [This paper] reviews three cases of systems of innovation operating in contrasting regional, socio-economic and agro-ecological contexts, in terms of four features of innovation systems more likely to build, sustain or enhance food security in situations of rapid change: (i) recognition of the multifunctionality of agriculture and opportunities to realize multiple benefits; (ii) access to diversity as the basis for flexibility and resilience; (iii) concern for enhancing capacity of decision makers at all levels; and

(iv) continuity of effort aimed at securing the well-being of those who depend on agriculture.

Credibility. Sally Brooks has a DPhil from the Institute of Development Studies at the University of Sussex. Michael Loevinsohn has a PhD in Ecology from Imperial College in London. Brooks and Loevinsohn are both researchers in the Knowledge, Technology and Society Group at the STEPS (Social, Technological and Environmental Pathways to Sustainability) Centre, Institute of Development Studies (IDS) at the University of Sussex. *Natural Resources Forum* is a peer-reviewed "United Nations Sustainable Development Journal." In addition, the sources cited for this article were a combination of peer-reviewed articles and government and non-governmental organizations.

Summary. This article, which discusses more with innovations in agricultural practices, also has several ideas about agricultural innovations that can be applied to knowledge sharing to enhance food security. Brooks and Loevinsohn discuss what kind of support is necessary to make innovation systems implementable. In order for innovation systems to be successful, they need to (a) facilitate access to diversity (of knowledge, crops, livestock, practices, etc.); (b) build capacity and encourage change and adaptation; and (c) maintain continuity of effort, as well as implement monitoring and evaluation systems. Technological innovations must be carefully considered and should not be "treated as an add-on to already 'finished' technologies" (p. 195). Any technological innovations should be purposeful and involve key stakeholders, including farmers as well as policy makers. Brooks and Loevinsohn emphasize that for any innovation systems to be successful, it is extremely important to involve the farmers, a key group that is often overlooked in policy making.

Gebbers, R., & Adamchuk, V. I. (2010). Precision agriculture and food security. *Science*, *327*(5967), 828-831. doi:10.1126/science.1183899

Abstract. Precision agriculture comprises a set of technologies that combines sensors, information systems, enhanced machinery, and informed management to optimize production by accounting for variability and uncertainties within agricultural systems. Precision agriculture provides a means to monitor the food production chain and manage both the quantity and quality of agricultural produce.

Credibility. Robin Gebbers has a PhD in Agronomy and is a Scientist in the Department of Agricultural Engineering at the Leibniz-Institute to Agricultural Engineering in Potsdam, Germany. Viacheslav Adamchuk has an MS and a PhD in Agricultural and Biological Engineering and is currently Associate Professor in Bioresource Engineering Department at McGill University in Montreal, Quebec. Between the two authors, they have published over 50 journal articles in the fields of agronomy, soil science, and precision agriculture. *Science* is a peer-reviewed journal, and the majority of the references cited by the article are published in peer-reviewed journals.

Summary. This article discusses the importance of using technology, particularly monitoring systems defined within the concept of precision agriculture, as a way to track and manage food supplies to ensure adequate quantities and quality. Precision agriculture is used to promote food traceability, agricultural management, and to increase productivity and quality of the food. Precision agriculture closely ties to food traceability systems to ensure food quality and to optimize production and access to food.

Golan, E., Krissoff, B., Kuchler, F., Calvin, L., Nelson, K., & Price, G. (2004). Traceability in the U.S. food supply: Economic theory and industry studies (Report No. 830).

Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 830. Retrieved from http://www.ers.usda.gov/publications/aer830/aer830.pdf

Abstract. This investigation into the traceability baseline in the United States finds that private sector food firms have developed a substantial capacity to trace. Traceability systems are a tool to help firms manage the flow of inputs and products to improve efficiency, product differentiation, food safety, and product quality. The best targeted government policies for strengthening firms' incentives to invest in traceability are aimed at ensuring that unsafe or falsely advertised foods are quickly removed from the system, while allowing firms the flexibility to determine the manner. Possible policy tools include timed recall standards, increased penalties for distribution of unsafe foods, and increased food borne-illness surveillance.

Credibility. Golan, Krissoff, Kuchler, Calvin, and Nelson were staff members at the United States Department of Agriculture (USDA) Economic Research Service at the time of publication. Gregory Price was an economist at the Commodity Futures Trading Commission at the time of publication. Elise Golan is Director of Sustainable Development. Golan has a PhD in agricultural economics from the University of California at Berkeley and completed a post-doctorate fellowship focusing on environmental economics at the University of Haifa, Israel. Barry Krissoff is Senior Agricultural Economist and has a PhD in Economics from the University of Virginia. Fred Kuchler is an Agricultural Economist and has a PhD in Economics from Virginia Polytechnic Institute and State University. Calvin, Nelson, and Price were all Economists for the Economic Research Service. The Economic Research Service, a division of the UDSA, is staffed by a combination of economists and social scientists who "conduct

research, analyze food and commodity markets, produce policy studies, and develop economic and statistical indicator" ("About ERS," para. 2). The article includes citations from other governmental studies.

Summary. This article strives to (a) define food traceability systems, (b) outline the benefits and relationship to food safety and security, and (c) suggest effective policies for implementing traceability systems. One of the key benefits of a nation-wide traceability system is the ability to improve food quality and safety. Traceability systems also allow the marketing of foods with different "undetectable quality attributes" (p. 4) at a lower price in lower socioeconomic markets. The increase in supply management will also allow food to be siphoned to areas with greater need with very little notice, and will increase the efficiency of distribution.

Nah, S., & Chau, C. (2010). Issues and challenges in defeating world hunger. *Trends in Food Science & Technology*, *21*(11), 544-557.

Abstract. Significant numbers of people suffering from hunger and food shortage are in a daily struggle to obtain food for survival. This article discusses the issues and challenges on scientific, environmental, technological, socio-economic, and political aspects in facing global food insecurity problems. A multifaceted strategy for the applications of science and technology, as a part of the solution, in defeating world hunger has also been discussed. The wealth of information will hopefully create a platform for discussion and sharing of knowledge on solving the food security problems around the world.

Credibility. Chi-Fai Chau has an MS in Food Science and Technology from Texas A&M University and a PhD in Biology from The Chinese University of Hong Kong. Fai is currently a Distinguished Professor in the Department of Food Science and

Biotechnology at the National Chung Hsing University in Taiwan. At the time of publication, Sui-Lin Nah was also associated with the Department of Food Science and Biotechnology at the National Chung Hsing University in Taiwan. *Trends in Food Science & Technology* is a peer-reviewed journal, and the majority of the references cited by this review article are published in peer-reviewed journals.

Summary. This article emphasizes the necessity of information and knowledge sharing and encourages that policies be developed to encourage infrastructure development, education, and the aforementioned knowledge sharing. Nah and Chau also mention several technologies that have the potential to improve food safety and security, including implementing food traceability systems (particularly RFID). However, the article emphasizes that one of the most important steps in achieving food security is the collection, exchange, and integration of knowledge, particularly the knowledge of the local farmers, which will, in turn, lead to the empowerment of the local communities.

Oger, R., Krafft, A., Buffet, D., & Debord, M. (2010). Geotraceability: An innovative concept to enhance conventional traceability in the agri-food chain. *Biotechnologie Agronomie Société Et Environnement*, *14*(4), 633-642.

Abstract. With the globalization of trade, people have become enlightened and demanding consumers as regards the origin of their food and the environment in which it is produced. The concept of geotraceability described in this article responds to that requirement by combining geographical information with conventional traceability data. The inclusion of geographical information relating to the environment of the production plots is based not only on exploiting some functionalities of spatial analysis tools that exist in geographical information systems (GIS) but also on developing specific tools such as a geoidentifier and geoindicators. This article also describes the characteristics and methods of implementing a geographical information management system linked with traceability information. Lastly, the potential for using geotraceability systems in supply chains is analyzed, in particular for consumer warnings in cases of food crisis and assistance for certification of differentiated quality agricultural products.

Credibility. Robert Oger is currently the head of the Biometry, Data Management and Agro-meteorology department of the Walloon Agricultural Research Centre (CRA-W). Alain Krafft and Dominique Buffet are also at CRA-W. Michel Debord is with the Chamber of Commerce in Auch, France. *Biotechnologie Agronomie Société Et Environnement* is a peer-reviewed journal and the references cited are equally divided between peer-reviewed articles and government sources.

Summary. This article discusses the most commonly used traceability systems and why they are being required and implemented by governments in Europe and America. Traceability systems at the farm level have the ability to positively impact food security by linking information and knowledge management with "technical or economic farm management" (p. 4). Implementing information and knowledge management systems at the farm level will not only enable knowledge sharing, but will also be able to integrate traceability systems that will increase internal and external quality management. Implementing geographical information into the traceability and information systems will enable a mapping component. The increasing availability of spatial mapping and GIS systems will enrich current systems. However, without open access systems, the resulting knowledge bases will not be available to farmers and other stakeholders in local food markers. Therefore, it is vital that any geotraceability system implemented takes into consideration that the knowledge providers (i.e. the local farmers and food distributors) and ensure that open access systems are used. If correctly executed, a geotraceability system “can be used in the implementation of agricultural decision support systems” (p. 10).

Popper, D. (2007). Traceability: Tracking and privacy in the food system. *Geographical Review*, *97*(3), 365-388.

Abstract. Lapses in food safety have spurred development of governmental traceability systems to track every stage of food production as part of a standardized information base. Traceability regulations require that, from farm (plant or animal) to fork, foods have a clear, verifiable record that tracks through all stages of cultivation, production, supplying, transporting, processing, and distribution. Traceability implies complete information control over the geography of one of life's most essential acts, eating. Those people responsible at each stage for food transfers and transactions may go into the traceability database, making their locations part of the record and supporting precise monitoring of labor performance, consumer buying patterns, and ownership and management strategies.

Credibility. Deborah Popper has a PhD from Rutgers and is Professor of Political Science, Economics, and Philosophy at the College of Staten Island/City University of New York. She is on the governing board of the American Geographical Society and has published several articles on traceability and other geographical concerns in peer-reviewed journals. *The Geographical Review* is a peer-reviewed journal, and Popper sites extensively from other peer-reviewed articles. Popper’s writing does show some bias against traceability in the food system as exhibited by the descriptive word *Orwellian*, but

Popper admits that much of the written opinion in the article is conjectural. Popper cites many sources that outline both the pros and cons of increased traceability and tracking in our food system.

Summary. This article discusses the implications of implementing food tracking and traceability requirements. The purpose of such a system is to be able to create “a standardized locational information systems that encompasses all food at all stages of production, from farm to fork” (p. 365). One of the aims of implementing traceability requirements is that it would improve food safety by letting consumers (or, more likely retailers) know all the locations the food item stopped at on its way to the market. Ideally, a traceability system would require a knowledge management system and would need to employ a radio frequency identification (RFID) system.

RFID systems can “improve distribution efficiency, particularly for perishable products” (p. 373), which would help get food to needed locations more quickly and ensure the safety of the perishable products. This system would require accessible databases of the RFID information, and those databases would need to be transparent to all stakeholders (farmers, intermediaries, retailers, and consumers). RFID scanning at the market level would also increase retailers’ knowledge of current inventory levels and sales, and allow for more targeted ordering.

Sugahara, K. (2009). Traceability system for agricultural products based on RFID and mobile technology. *Computer and Computing Technologies in Agriculture II, Volume 3, 295*, 2293-2301.

Abstract. In agriculture, it is required to establish and integrate food traceability systems and risk management systems in order to improve food safety in the entire food chain.

The integrated traceability system for agricultural products was developed, based on innovative technology of RFID and mobile computing. In order to identify individual products on the distribution process efficiently, small RFID tags with unique ID and handy RFID readers were applied. Based on this system, agricultural risk management systems have been developed. These systems collaborate with traceability systems and they can be applied for process control and risk management in agriculture.

Credibility. Koji Sugahara, PhD, is a Senior Research Scientist for the National Agricultural Research Organization in the Division of Agricultural Systems and Information Technology in Japan. *Computer and Computing Technologies in Agriculture II, Volume 3* is a collection of peer-reviewed articles from The Second IFIP International Conference on Computer and Computing Technologies in Agriculture. In addition, the majority of the references cited in this article are from peer-reviewed journals, although most of them have been published in Japanese.

Summary. This article states that food traceability systems, when implemented correctly, can improve food safety and quality, and thus positively affect food security. The food traceability systems that are discussed make use of existing ICT systems, including Internet and mobile phones, as well as RFID technology, to allow individuals from farmers down the supply chain to consumers, to have access to food tracking information. These systems improve efficiency of both production and distribution. One barrier to worldwide implementation of this solution is current costs, although RFID technology is getting less expensive every year. The systems are well received by both consumers and marketers, and have been proven to mitigate food safety risks.

Zaks, D. P. M., & Kucharik, C. J. (2011). Data and monitoring needs for a more ecological agriculture. *Environmental Research Letters*, *6*(1), 014017. doi:10.1088/1748-9326/6/1/014017

Abstract. As demands grow for increasing agricultural output while reducing its negative environmental impacts, both existing and novel data sources can be leveraged to provide more information to producers, consumers, scientists and policy makers. We review the components and organization of an agroecological sensor web that integrates remote sensing technologies and *in situ* sensors with models in order to provide decision makers with effective management options at useful spatial and temporal scales for making more informed decisions about agricultural productivity while reducing environmental burdens. Several components of the system are already in place, but by increasing the extent and accessibility of information, decision makers will have the opportunity to enhance food security and environmental quality.

Credibility. David Zaks has a BS in Environmental Science and Management with a specialization in spatial information processing (GIS/Remote Sensing) and is currently a PhD student at the University of Wisconsin - Madison in the Center for Sustainability and the Global Environment. Christopher Kucharik has a PhD in Atmospheric Sciences and is Associate Professor of Agronomy & Environmental Studies at the Center for Sustainability and the Global Environment at the University of Wisconsin-Madison. *Environmental Research Letters* is a peer-reviewed journal. The majority of references cited by this article are from peer-reviewed sources, with the remainder being mostly from government publications.

Summary. This article discusses the way that farmers' management decisions can be supplemented by knowledge gained from precision agriculture tools such as satellites, computer monitors, and sensors. Precision agriculture works with information management systems and spatial analysis to expand current agroecological monitoring and aid in coordination and communication between governments, private industry, and farmers. Technologies that can be used to improve both production and marketing include on-farm monitoring, imaging systems, and wireless systems, but only if the necessary infrastructure can be put into place. Benefits of increased use of precision agriculture, including wireless monitoring, include increased yield, decreased costs, and increased food availability and traceability.

Conclusions

This annotated bibliography presents and summarizes 30 articles that discuss the ways that existing information and communication technologies, including GIS and knowledge management systems, can be used by the State of Oregon to increase food security. Food security and potential technological solutions are described in both rural and urban areas in the United States, Canada, the Middle East, Asia, and Africa. These technologies can all be translated into usable suggestions and policies for the state of Oregon.

Specifically, this annotated bibliography identifies and describes promising and widely used ICT tools that can be used to support information and knowledge management related to food security (Chowdhury, 2001; Deichmann & Wood, 2001; Gareau, 2004). Tools that are identified include (a) information and knowledge networks connecting local farmers, markets, and policy makers (Ballantyne, 2009); (b) improved and accessible databases of food resources (Gareau, 2004); (c) mobile phones for and appropriate infrastructure to connect farmers and other food producers to real-time market and distribution agents (Ingram, 2011); (d) GIS mapping access and analyses (Charreire et al., 2010); (e) community food assessments (CFAs) (Pothukuchi, 2004); (f) agroecological innovation systems (Altieri, 2001); (g) food traceability systems to enhance food safety (Golan et al., 2004); and (h) food and agriculture monitoring and tracking systems (Zaks & Kucharik, 2001).

Although several technologies are identified that show strong potential to affect food security in positive ways in both rural and urban areas in Oregon, the summarized references indicate that there are two vital factors that need to be considered in order to make any technological implementation successful: (a) investment in adequate infrastructure (Altieri, 2002; Chowdhury, 2001; Gareau, 2004; Kamssu et al., 2004; Larsen et al., 2010; Lashgarara et al., 2011; Lashgarara et al., 2008; McLaren et al., 2009; Yaghoobi & Sarani, 2011) and (b) open access by all involved stakeholders (e.g. farmers, policy makers, appropriate non-governmental organization employees, distributors, and suppliers) to the developed information and knowledge databases (Ballantyne, 2009; Hwang & Smith, 2010; McLaren et al., 2009; Oger et al., 2010; Zaks & Kucharik, 2011).

Food Insecurity and Information and Communication Technology Tools

ICT can be used to positively affect rural and urban development through infrastructure building, diffusion of mobile phones, and the pooling and dissemination of knowledge. Several tools and approaches are identified (see Table 3). In addition, several authors emphasize the necessity of recognizing the non-technological features needed to guarantee a successful implementation of any new ICT tools (see Table 4).

Food insecurity is more a result of insufficient access to food, rather than insufficient food production (Ingram, 2011). Policy makers must consider both geographic and economic access when planning ICT development in rural areas (Larsen et al. 2010). When local farmers are able to connect with each other and access up-to-date market information, trends, and new technologies, both financial decision making and food production and distribution are improved (Lashgarara et al. 2011; Lashgarara et al., 2008). Yaghoobi and Sarani (2011) state that "knowledge and information are the main elements of food security and that they are essential for facilitating rural divilopment [sic] and creating economic and social changes" (p. 444).

ICT tools to affect food security. Several forms of ICT provide excellent tools to improve food security. Tools include (a) new technologies (e.g. Internet, mobile phones, web conferencing), (b) old technologies (e.g. radio, phone, and television), and (c) other forms of communication (e.g. workshops, printed materials, and conferences) (Lashgarara et al., 2011) (see Table 3). Internet connections and mobile, wireless phones are considered to be two of the most effective ICT tools to positively affect food insecurity in rural areas. These tools connect small agricultural producers (e.g. farmers) with local, regional, and global markets, and can improve business processes, production decisions, and supply chains and distribution (Chowdhury, 2001). The implementation of web sites, email groups, or listservs accessible by or distributed to farmers, food distribution organizations, and other stakeholders can improve communication and enhance local knowledge (Gareau, 2004).

Farmers with mobile phone and Internet access are able to (a) retrieve better crop information, (b) stay current on agricultural trends and technologies, and (c) respond in a timely fashion to changes in demand (McLaren et al., 2009). Although mobile phones are easy to deploy to remote areas due to the lack of additional infrastructure needs and can immediately increase communication between individuals and other stakeholders in rural development and food security, they are less capable of expanding into a wide-spread knowledge sharing tool; this means that Internet connectivity also needs to be considered a vital piece of ICT in rural development (Larsen et al. 2010).

Because food security depends on food availability, food accessibility (both economic and geographic), and food utilization, it is important that any suggestions for the use of ICT to positively affect food security take those three aspects into account. Ingram (2001) states that ICT can positively impact food security outcomes in the following ways:

1. Food availability is increased by using Internet access to aid communication between producers and increase food production.
2. Geographic food access is enhanced by using (a) ICT to improve distribution and enable Internet ordering and (b) GIS for better forecasting. Geographic access can

also be improved by implementing (a) food exchange via cell phone technology to aid producers in finding the best local markets and (b) e-commerce to increase and encourage trade and data exchange.

3. Economic food access is further developed by using web connectivity to inform consumers and GIS to reduce production costs, thus increasing food affordability.
4. Food utilization is enhanced by increasing food safety through (a) smart packaging, (b) food monitoring, and (c) food tracking and traceability.

Table 3

Effective ICT tools for reducing food insecurity

Effective ICT tools	**Citations**
Communications technology, described as: conferences, email and/or listservs, mobile phones, printed materials, telecommunications, telephones	Chowdhury, 2001; Deichmann & Wood, 2001; Gareau, 2004; Kamssu, Siekpe, & Ellzy, 2004; Lashgarara, Mirdamadi, & Hosseini, 2011; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009; Zaks & Kucharik, 2011
Information and communication technologies (ICT), described as: databases, ecommerce systems, GIS, internet, mobile phones, RFID technology, telecommunications, web conferencing, world wide web	Ballantyne, 2009; Chowdhury, 2001; Deichmann & Wood, 2001; Gareau, 2004; Ingram, 2011; Kamssu, Siekpe, & Ellzy, 2004; Larsen, Powell, Sriskandarajah, & Peterson, 2010; Lashgarara, Mirdamadi, & Hosseini, 2011; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009; Nah & Chau, 2010; Sugahara, 2009; Yaghoobi, & Sarani, 2011; Zaks & Kucharik, 2011
Information technology, described as: databases, ecommerce systems, internet, inventory systems, websites, world wide web	Ballantyne, 2009; Gareau, 2004; Larsen, Powell, Sriskandarajah, & Peterson, 2010; Lashgarara, Mirdamadi, & Hosseini, 2011; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009
The Internet, described as: communications networks of connected individuals and organizations, websites, world wide web	Ballantyne, 2009; Chowdhury, 2001; Gareau, 2004; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009
Knowledge sharing, described as: databases of pooled information and	Chowdhury, 2001; Deichmann & Wood, 2001;Larsen, Powell, Sriskandarajah, & Peterson, 2010; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; McLaren, Metz,

knowledge that are accessible to all stakeholders, including farmers and other food producers; communications networks including email distribution lists and listservs designed to collect and share information	Berg, Bruskiewich, Magor, et al., 2009
Mobile phones, described as: wireless phones that rely on satellites or cellular towers, one method of connectivity in remote areas.	Chowdhury, 2001; Lashgarara, Mirdamadi, & Hosseini, 2011; Larsen, Powell, Sriskandarajah, & Peterson, 2010; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009; Sugahara, 2009
Telecommunication, described as: methods of communication that involve transmitting information over great distances ("Telecommunication, n.d.), in this instance, specifically *phone* technologies and the internet.	Chowdhury, 2001; Kamssu, Siekpe, & Ellzy, 2004; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009

ICT approaches/investments. The local farmer is the key player in rural innovation systems, and it is vital that the famer has the means and ability to document experiences and knowledge via ICT (Larsen et al., 2010). In order for that to happen, it is necessary that information and communication specialists work with the farmers to ensure that the knowledge is shared and utilized (Ballantyne, 2009).

The main investments that demonstrate the largest affect on ICT access in rural areas are (a) infrastructure and (b) open access software (Ballantyne, 2009, Chowdhury, 2001) (see Table 4). Chowdhury (2001) states that investing in rural telecommunications and ICT infrastructure will not only link farmers together, enabling knowledge sharing, but also ensure that market information is available to producers and distributors.

Without affordable and reliable Internet access, equipment, and telecom services, the spread of e-commerce and rural development will be stunted (Kamssu et al. 2004). Currently, the main obstacle for most rural ICT development is the lack of infrastructure, although Larsen, Powell, Sriskandarajah, and Peterson (2010) state that with cooperation between local governments, non-governmental organizations, and other stakeholders, ICT access can be increased in rural areas.

The increased access not only allows farmers to share information with each other (Yaghoobi & Sarani, 2011), but will also (a) encourage them to be more competitive when entering the marketplace by supplying up-to-date information about food and agricultural markets; (b) improve business profitability; and (c) improve and diversify rural economies (Lashgarara et al. 2008).

Table 4

Necessary ICT investments and approaches for reducing food insecurity

Investment/Approach	**Citations**
Agricultural development, described as: changes and adaptations to traditional and current agricultural practices; enrichment of knowledge that aids productivity, efficiency, and profitability	Ballantyne, 2009; Larsen, Powell, Sriskandarajah, & Peterson, 2010; Lashgarara, Mirdamadi, & Hosseini, 2011; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008
Agricultural information, described as: information on agricultural innovations, tools, and practices; includes current trends in both production and distribution and sales	Larsen, Powell, Sriskandarajah, & Peterson, 2010; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009
Agricultural research, described as: research on the current and past practices, technologies, and tools used in agriculture with the purpose to develop new innovations	McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009
Appropriate technology, described as: technology that takes into account the resources and infrastructure available for those intended to use it	Altieri, 2002; Chowdhury, 2001; Deichmann & Wood, 2001; Gareau, 2004; Larsen, Powell, Sriskandarajah, & Peterson, 2010; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009

Infrastructure, described as: the physical structures and systems that need to be in place for internet, knowledge sharing, and telecommunications technologies to be available and accessible by the targeted users	Altieri, 2002; Chowdhury, 2001; Gareau, 2004; Kamssu, Siekpe, & Ellzy, 2004; Larsen, Powell, Sriskandarajah, & Peterson, 2010; Lashgarara, Mirdamadi, & Hosseini, 2011; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009; Yaghoobi & Sarani, 2011
Innovation systems, described as: new developments, tools, technologies and practices that increase productivity and enhance information exchanges	Ballantyne, 2009; Brooks & Loevinsohn, 2011; Chowdhury, 2001; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009; Zaks & Kucharik, 2011
Rural development, described as: increasing infrastructure to enhance connectivity and communication in rural areas, elimination of the *last mile* problem	Ballantyne, 2009; Chowdhury, 2001; Deichmann & Wood, 2001; Gareau, 2004; Kamssu, Siekpe, & Ellzy, 2004; Larsen, Powell, Sriskandarajah, & Peterson, 2010; Lashgarara, Mirdamadi, & Hosseini, 2011; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009; Yaghoobi, & Sarani, 2011

Geographic Information Systems and Production and Distribution of Food

GIS combined with knowledge of local food systems can be used to positively affect food security and eliminate both rural and urban food deserts using community food assessments, spatial mapping, and analysis (Charreire et al., 2010; Eckert & Shetty, 2011; McEntee & Agyeman, 2010; Pothukuchi, 2004; Russell & Heidkamp, 2011; Wu, Tang, et al., 2011; Wu, Yang, et al., 2011). Urban planners and local governmental policy makers are key stakeholders who can make these changes. Food production and geographical food access are not direct corollaries; therefore, a measurement of food production does not necessarily answer questions about food security. As discussed previously, access (both geographic and economic) is one of the key foundations to food security (Charreire et al., 2010; Deichmann & Wood, 2001; Eckert & Shetty, 2011; Hwang & Smith, 2010; Russell & Heidkamp, 2011). GIS and related mapping tools (see Table 5) as well as policies and approaches related to GIS (see Table 6) can be used to reduce food insecurity in both rural and urban settings.

GIS tools for reducing food insecurity. According to Charreire et al. (2010), analyzing both density of food outlets and residential proximity to food is necessary to accurately assess inequalities in access. GIS mapping provides an important advantage in these assessments and allows urban planners and policy makers to visualize urban geographic access to food (Charreire et al., 2010; Russell & Heidkamp, 2011). Including socioeconomic overlays with geographic features in GIS food system mapping and development can help protect and promote food security (Gregory et al., 2005). Eckert and Shetty (2011) agree that urban planners paired with GIS analysis can make a positive impact on geographic and socioeconomic access to food, both through planning market locations and by incorporating plans for urban agriculture such as community gardens.

GIS mapping is also critical to rural development when it comes to geographic food access (Deichmann & Wood, 2001). In addition to providing information about food outlet density and proximity, GIS and spatial technology improve information gathering and promote knowledge sharing through web mapping and spatial inventories (Deichmann & Wood, 2001). This mapping provides increased information not only about geographic access, but also about socioeconomic conditions, and can help rural planners in determining what infrastructure is needed to improve food security (Deichmann & Wood, 2001).

Ostry and Morrison (2009) suggest that the development of a geospatial database to track and report on GIS maps containing geographic and socioeconomic data would improve knowledge about both food production and distribution, as well as inform policy makers and planners where rural and urban food deserts are located, thus improving targeted food production and distribution. Pothukuchi (2004) proposes getting that data through community food assessments, and using that information to not only build geospatial databases, but also to (a) build community relationships, (b) improve information and knowledge sharing, and (c) aid in both urban and rural resource location and infrastructure development planning.

Wu, Tang, et al. (2011) and Wu, Yang, et al. (2011) recommend using GIS mapping technology and spatial analysis to not only determine where current food deserts are located, but also to overlay this information with climate model predictions to determine where future food production and distribution problems will occur. This mapping and analysis will proactively and positively influence future food security to better inform urban and rural planning and policy (Wu, Tang, et al., 2011; Wu, Yang, et al., 2011).

Table 5

GIS tools for reducing food insecurity

GIS tools	**Citations**
Choropleth, thematic, and web mapping, described as: easy to interpret maps with several layers that can be overlaid to provide a complete picture of economic, geographic, and demographic information	Charreire, Casey, Salze, Simon, Chaix, et al., 2010; Deichmann & Wood, 2001; McEntee & Agyeman, 2010; Hwang & Smith, 2010; Oger, Krafft, Buffet & Debord, 2010; Ostry & Morrison, 2009; Pothukuchi, 2004; Russell & Heidkamp, 2011; Wu, Tang, et al., 2011; Zaks & Kucharik, 2011
Geographic information systems (GIS), geospatial information technology, and global navigation satellite systems (GNSS), described as: systems and databases that gather and store information about geographic data, collected through satellite systems and shared and accessed through global positioning systems and mapping	Charreire, Casey, Salze, Simon, Chaix, et al., 2010; Deichmann & Wood, 2001; Eckert & Shetty, 2011; Gebbers & Adamchuk, 2010; Hwang & Smith, 2010; Ingram, 2011; McEntee & Agyeman, 2010; Oger, Krafft, Buffet & Debord, 2010; Ostry & Morrison, 2009; Pothukuchi, 2004; Russell & Heidkamp, 2011; Wu, Tang, et al., 2011; Wu, Yang, et al., 2011; Yaghoobi, & Sarani, 2011; Zaks & Kucharik, 2011
Geographical data, described as: data gathered and recording in geographic information systems and maps	Hwang & Smith, 2010; Ostry & Morrison, 2009

Geocoding, geoidentifier, geoindicator, described as: coding systems that help identify specific geographical functions for use in GIS and mapping	McEntee & Agyeman, 2010; Oger, Krafft, Buffet & Debord, 2010; Ostry & Morrison, 2009
Spatial analysis, described as: an analysis of the information gathered and shared for GIS systems; aids in making accurate and useful maps; can show precise current information and help create future forecasts	Charreire, Casey, Salze, Simon, Chaix, et al., 2010; Deichmann & Wood, 2001; Hwang & Smith, 2010; Ostry & Morrison, 2009; Pothukuchi, 2004; Russell & Heidkamp, 2011; Wu, Yang, et al., 2011; Zaks & Kucharik, 2011;

GIS policies and approaches for reducing food insecurity. Planning (both rural and urban) is one of the key ways GIS data and analysis can be used to improve food security and reduce the presence of food deserts based on both economic and geographic access. In addition to the utilization of this data in planning, questions of availability and access need to be addressed. Hwang and Smith (2010) state that GIS maps to be utilized for food security and related reasons need to be affordable, easily accessible, and easily utilized by all stakeholders. The development and use of open access web mapping tools is critical to the success of comprehensive mapping in areas that do not have the financial resources to invest in expensive mapping software systems (Hwang & Smith, 2010). Ostry and Morrison (2009) agree and go on to propose that open source and publicly available databases and maps can be used not just by local and state governments and urban planners when developing policy, but should also be accessible and usable by farmers, educators, and community activists. With access to geospatial maps and analysis, farmers and other key stakeholders can influence policies and take an active part in rural and urban planning (Charreire et al., 2010), thus improving community food security (Charreire et al., 2010; Deichmann & Wood, 2001; Hwang & Smith, 2010; Pothukuchi, 2004) and helping to eliminate both rural and urban food deserts (Eckert & Shetty, 2011; McEntee & Agyeman, 2010; Russell & Heidkamp, 2011).

Table 6

GIS policies and approaches for reducing food insecurity

GIS policy or approach	Citations
Community food security (CFS), described as: food security at a geographically defined level (e.g. an urban neighborhood, a rural township, etc.)	Charreire, Casey, Salze, Simon, Chaix, et al., 2010; Deichmann & Wood, 2001; Hwang & Smith, 2010; Pothukuchi, 2004
Food desert, described as: an area, either rural or urban, that lacks ready access (either geographic or economic) to a consistent source of plentiful food	Eckert & Shetty, 2011; McEntee & Agyeman, 2010; Russell & Heidkamp, 2011
Local food/local food systems, described as: the production and distribution of food within a defined geographic area (e.g. an urban neighborhood, a rural township, etc.)	Gregory, Ingram, & Brklacich, 2005; Hwang & Smith, 2010; Ingram, 2011; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; Oger, Krafft, Buffet & Debord, 2010; Ostry & Morrison, 2009; Pothukuchi, 2004; Wu, Tang, et al., 2011
Open source/ access, described as: unrestricted access to information such as GIS maps, knowledge bases, databases, etc. via the internet Open source software is software that is free to use, edit, and redistribute (“Open Source,” n.d.).	Ballantyne, 2009; Hwang & Smith, 2010; McLaren, Metz, Berg, Bruskiewich, Magor, et al., 2009; Oger, Krafft, Buffet & Debord, 2010; Zaks & Kucharik, 2011
Urban planning, described as: Government plans to ensure that food distribution points within an urban environment are deliberately and purposefully laid out to best benefit all citizens	Eckert & Shetty, 2011; McEntee & Agyeman, 2010; Ostry & Morrison, 2009; Pothukuchi, 2004; Russell & Heidkamp, 2011

Food Safety and Security and Knowledge Management Systems

Food safety is a vital component of food security (Golan et al., 2004). Through various knowledge management systems, including agroecology and food traceability and tracking systems, food safety can be improved, thus positively affecting food security.

The third tenet of food security is food utilization, which is affected by food safety. Food safety and quality can be positively impacted by food traceability and tracking systems (Golan et al., 2004). In addition, food traceability systems can help redistribute foods at lower prices in areas with greater economic need, often with little notice, thus increasing distribution efficiency (Golan et al., 2004). Radio frequency identification (RFID) barcodes are one way of incorporating traceability capacity into food (Sugahara, 2009).

In addition to incorporating traceability via RFID technology, it is important to encourage and support agricultural innovations (Altieri, 2002; Sugahara, 2009) such as precision agriculture (Gebbers & Adamchuk, 2010; Zaks & Kucharik, 2011) (see Table 7), as well as implement policies that encourage agroecological innovations (Altieri, 2002; Zaks & Kucharik, 2011) and promote information and knowledge sharing and resource management practices (Altieri, 2002; Brooks & Loevinsohn, 2011; Gebbers & Adamchuk, 2010; Golan et al., 2004; Nah & Chau, 2010; Oger et al., 2010; Popper, 2011; Sugahara, 2009; Zaks & Kucharik, 2011) (see Table 8).

Information and knowledge management tools to increase food safety. Although food traceability systems are not yet required by the United States government, Golan et al. (2004), on behalf of the United States Department of Agriculture, make a very strong case for implementing federal traceability standards to improve food quality and safety. Oger, Krafft, Buffet, and Debord (2010) state that traceability systems implemented at the farm level can positively impact food security by (a) linking information and knowledge management with agricultural innovations, (b) enabling knowledge and information sharing, and (c) increasing internal and external quality management. Additionally, adding geographical information into the traceability systems will enable a mapping component and allow traceability systems to work with GIS and spatial analysis programs, to increase both food safety and food access (Oger et al., 2010).

RFID technology would standardize food traceability systems, and would allow this information to be included as an overlay in GIS maps (Popper, 2011). In addition, RFID tracks food from production to distribution, and would decrease food spoilage, thus increasing quality and safety (Popper, 2011). Sugahara (2009) states that RFID technology can use existing ICT infrastructure, including Internet and mobile phones, which would improve the efficiency of distribution systems as well.

In addition to implementing RFID traceability systems, other technologies that are applicable to knowledge management and food security and safety include agricultural innovation systems, such as precision agriculture. Monitoring systems, as a part of precision agriculture, can be implemented at the farm level to ensure that food production is meeting quality and safety standards, and can assist in the tracking and management of food supplies (Gebbers & Adamchuk, 2010). Satellites and GIS systems contribute to precision agriculture by expanding agroecological monitoring and enhancing coordination and communication between governments, food suppliers, producers, and distributors (Zaks & Kucharik, 2011). These monitoring and precision agricultural tools improve food safety and security by helping to increase yield, decrease costs, and increase food availability and traceability (Zaks & Kucharik, 2011).

Table 7

Information and knowledge management tools to increase food safety

Information and Knowledge Management Tools	**Citations**
Agricultural innovation systems, described as: agroecology, precision agriculture, food traceability, RFID	Altieri, 2002; Sugahara, 2009
Food traceability (traceability/tracing/tracking/traceback); geotraceability, described as: tracking food from farm to consumer, RFID technology, agricultural innovation	Gebbers & Adamchuk, 2010; Golan et al., 2004; Oger, Krafft, Buffet & Debord, 2010; Popper, 2011; Sugahara, 2009; Zaks & Kucharik, 2011
Neo- precision agriculture, described as: tools such as satellites, monitors, and sensors that enhance production and efficiency	Deichmann & Wood, 2001; Gebbers & Adamchuk, 2010; Zaks & Kucharik, 2011
Product differentiation, described as: small, nearly invisible differences between otherwise identical products that allow a product to be sold at a discount in lower socio-economic neighborhoods	Golan et al., 2004;
RFID, described as: a radio-identification technology that can be attached to food products to be used for food tracking and traceability	Popper, 2011; Sugahara, 2009;

Information and knowledge management approaches and policies to increase food safety. In order to successfully implement food traceability and agroecological innovations, Brooks and Loevinsohn (2011) state that it is necessary to build and support access to technological tools (including Internet and ICT tools, as well as mapping tools and databases) and to build the infrastructure necessary to support traceability and monitoring systems. In addition, any knowledge management systems put into place need to involve input from all key stakeholders, including the farmers and other food producers (Brooks & Loevinsohn, 2011).

Altieri (2002) and Nah and Chau (2010) agree that the most important aspects of implementing knowledge management systems to promote food safety and security are investment in infrastructure and tapping into the knowledge of the local farmers. Altieri (2002) states that knowledge management systems must link farmers to all other stakeholders, in order to utilize local knowledge and implement new agroecological systems.

Oger et al. (2010) emphasize that without open access systems, the resulting knowledge bases will not be available to farmers and other stakeholders in local food markers, and therefore it is vital that any new systems designed to track and manage food supply must take into consideration the access of the knowledge providers.

Table 8

Information and knowledge management approaches and policies to increase food safety

Information and Knowledge Management Approaches and Policies	**Citations**
Agroecology, described as: agricultural innovation that looks at the effects of various technologies on the ecology of the geographic area	Altieri, 2002; Deichmann & Wood, 2001; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; Zaks & Kucharik, 2011
Information management, described as: gathering, storing, and sharing the collective information that comes from both farmers and policy makers	Brooks & Loevinsohn, 2011; Gebbers & Adamchuk, 2010; Golan et al., 2004; Nah & Chau, 2010; Oger, Krafft, Buffet & Debord, 2010; Popper, 2011; Pothukuchi, 2004; Sugahara, 2009; Yaghoobi, & Sarani, 2011; Zaks & Kucharik, 2011
Knowledge management, described as: using the collected information to enact new policies, incorporate new technologies, and discover new innovations to increase productivity, efficiency, and profitability	Altieri, 2002; Brooks & Loevinsohn, 2011; Gebbers & Adamchuk, 2010; Nah & Chau, 2010; Popper, 2011; Yaghoobi, & Sarani, 2011; Zaks & Kucharik, 2011

Natural resource management, described as: managing available resources, including farm land, with agricultural innovations to encourage increased productivity, distribution, and ecological responsibility	Altieri, 2002; Gebbers & Adamchuk, 2010; Hwang & Smith, 2010; Larsen, Powell, Sriskandarajah, & Peterson, 2010; Lashgarara, Mirdamadi, Hosseini, & Chizari, 2008; Pothukuchi, 2004; Zaks & Kucharik, 2011

Application of Findings in Oregon

ICT systems are demonstrated to be a viable way to improve food security, and there are a number of available tools that require minimal financial commitment to implement, and would be easy and economical to employ in Oregon. Although little research is found that directly describes ways that technology can be put into practice to improve food security in Oregon, findings from Sparks, Bania, and Leete (2009) indicate that GIS mapping to locate food deserts in the Portland, Oregon metropolitan area yields useful results, showing that "14 of 24 high poverty census tracts in the urban area have Low to Very Low food access" (p. 24). Since household food insecurity in Oregon has risen every year since 2008 ("2010-2011 Annual Statistics," 2011), it is likely that urban food deserts will continue to be a prevalent issue in Oregon.

ICT, GIS, and traceability systems are interconnected, as they require similar infrastructures, tools, and policies to be successful. By implementing local, regional, and statewide policies that support infrastructure development, education, and utilization of local knowledge, Oregon can positively impact growing food insecurity with many of the tools already in existence. Conducting community food assessments (Pothukuchi, 2004) and creating layered maps with this information and GIS data already available can help urban and rural planners identify areas with low socioeconomic and/or geographic access to food and plan for ways to make distribution to these neighborhoods more accessible and affordable (Eckert & Shetty, 2011; McEntee & Agyeman, 2010; Russell & Heidkamp, 2011).

By ensuring that information is accessible to farmers, other food producers, supply-chain participants, policy-makers, and other key stakeholders (Hwang & Smith, 2010), Oregon can create information and knowledge networks (Ballantyne, 2009) to connect all interested parties and encourage the sharing of new innovations (Altieri, 2001), market data, and improve food quality, safety, and distribution efficiency (Deichmann & Wood, 2001). Implementing USDA recommended traceability systems will not only improve food safety, but will also provide consumers with more information about food origin (Golan et al., 2004).

This study supports the claim that it is clear that ICT will play a larger role in food management and traceability (Zaks & Kucharik, 2011). Government programs make GIS data more available, enabling (a) better spatial analysis to promote identification of food deserts (Eckert & Shetty, 2011; McEntee & Agyeman, 2010; Russell & Heidkamp, 2011), (b) increased ability to predict food shortages (Wu, Tang, et al., 2011; Wu, Yang, et al., 2011), and (c) increased traceability and monitoring to improve food safety (Zaks & Kucharik, 2011). By promoting and implementing these new technologies with input from all stakeholders, Oregon can begin to reverse the growing food insecurity in the state.

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