MICHIGAN STATE UNIVERSITY | Global Center for Food Systems Innovation

Assessing the Role of Information and Communication Technologies to Enhance Food Systems in Developing Countries

WHITE PAPER
2013 SERIES

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Information and Communication Technology for Development[1]

1. Introduction

For decades, scholars have recognized the important role that information and communication technologies (ICT) can play in supporting development goals. ICTs can bring high value information to the world's poor; for example, information on improved techniques for farming, access to education and health services, and access to government services. The earliest work often treated communication and information technology separately. The communication field first focused on traditional mass media (Schramm, 1964) and later telephones (Hudson, 1984) as tools for reaching economic and social development goals, while information technology specialists prior to the 1990s pursued the use of computers especially for public sector applications as well as to enhance the activities of multinational companies operating in developing regions (Heeks, 2008). With the convergence of telecommunications and computing and the rise of the Internet in the 1990s, ICT for development (ICT4D) entered a new phase characterized by efforts to use Internet-connected computers to deliver information and services to rural populations. However, because of inadequate telecommunications and electrical infrastructures across the developing world and the relatively high costs of personal computers, ICT4D projects in this period were largely based on deploying rural telecenters relying on satellites for Internet access (Heeks, 2008). As Heeks notes, these efforts struggled to attain sustainability and sufficient scale, and evaluation was often limited to case studies and anecdotal evidence of impact.

The period since 2000 represents yet another phase of ICT4D work, termed ICT4D 2.0 by Heeks (Heeks, 2008). Wireless communications and mobile devices are the defining elements of this new phase, which is inspired by the explosion in mobile phone subscriptions across the developing world. Today, for example, the African mobile market is the second largest in the world, trailing only the Asia Pacific region (GSMA, 2011). Across the developing world, there are now nearly 90 mobile subscriptions for every 100 people following a decade of extraordinary growth (ITU, 2013). Hence in the past decade, there has been considerable emphasis on the use of mobile phones as the primary means of delivering information and services to those in developing regions, including the world's poorest countries (Aker & Mbiti, 2010; Kelly & Minges, 2012; Lokanathan & de Silva, 2010).

Many ICT4D projects target the agricultural sector, including services aimed at small farmers (World Bank, 2011). Smallholder farmers[2] are considered key to food security in developing regions, where they constitute the majority of the rural poor (Dixon,

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[2] According to the FAO, "the term 'smallholder' refers to their limited resource endowments relative to other farmers in the sector" 9/29/13 10:52 PM.

Taniguchi, Wattenbach, & Tanyeri-Arbur, 2004). According to the Food and Agriculture Organization (FAO), smallholder farmers dominate farming systems in developing countries, accounting for most of the food production in these areas (Dixon et al., 2004). Thus, across the developing world are literally hundreds of examples of services aimed at this population including farmer advisory and extension services, market price information systems, systems that facilitate buyer-seller matching, weather alerts, and systems for mobile payment and financial services that have been developed for agricultural and food systems (Donovan, 2011). [3]

ICTs can thus be critical tools to help address food system challenges identified in the companion white papers prepared by researchers with the Global Center for Food Systems Innovation (Global Center for Food Systems Innovation (GCFSI), 2013a, 2013b, 2013c). For example, to address the challenges raised by climate change, ICTs can be important tools in helping smallholder farmers better adapt to hotter and dryer climates with applications that provide such decision support about the best times plant, water, and fertilize crops given changing weather patterns. Farmer information and advisory systems and other forms of extension augmentation, such as through participatory radio and video, entertainment media, interactive voice response, and text-based systems, can further be employed to educate farmers about the changing weather patterns and the implications for food production practices. To support food system transformations that can help countries experience rapid urbanization, ICTs can be leveraged to enhance efficiencies in market systems. Examples discussed later in this report are market information systems that not only provide data on prices but support trade facilitation by helping to aggregate small sellers and link buyers with sellers. Such tools can help farmers, traders, food wholesalers, and food retails more efficiently provide food to support urban markets. Lastly, ICT-based innovations have strong implications for the kinds of training and education strategies needed to address the growing skill gaps in the food system value chain. As will be shown later in this report, such approaches as participatory radio and video and on-demand access to information via interactive voice response and SMS can be important tools, especially to reach farmers, that complement more traditional education strategies as well as online learning in facilities with computers and Internet access.

This white paper has two primary purposes: 1) to summarize the key insights gleaned from prior work applying ICTs in support of agriculture and food systems, identifying approaches and opportunities that hold promise for enhancing global food security, and 2) to identify important knowledge gaps that remain, offering guidance for new work that investigates how to apply information and communication technologies in agriculture. In this year 1 white paper, the focus is on the East Africa region, with later white papers providing deeper coverage of ICT4D work in South and East Asia as well as West Africa. Following the introduction, Section 2 examines the basic state of the ICT infrastructure in the developing world, with a primary focus on the state of

[3] Also see http://markets.ischool.berkeley.edu/projects/ for a listing of over 200 ICT projects targeting agriculture.

Internet and mobile access. Section 3 provides a broad overview of recent ICT in agriculture projects. Section 4 examines research on the effectiveness of ICT for agriculture implementations. Section 5 contains the results of a field assessment of small farmers' use of mobile phones and market information services conducted by GCFSI researchers in Kenya in June of 2013. Based on the literature review and field assessment, Section 6 outlines a set of problem definitions to help guide future work and concluding remarks are provided in Section 7.

2. The ICT Infrastructure in the Developing World: Explosive Growth But Access Issues Remain

In order to set the stage for a discussion about the use of ICTs in support of food systems innovation, it is important to first describe the current state of the ICT infrastructure in developing regions. The ICT4D field[4] has a broad view of what is considered ICT and includes the devices for information processing, communications, and display, as well as the network services that transmit communication services and content (UNCTAD, 2011). Both new and traditional media are considered relevant, including radios, televisions, print media, fixed and mobile telephones, desktop and laptop computers, and notepads as access devices (often called "appliances"). Network applications and services can include the Internet and web-based applications, cellular networks, SMS/text message services, WiFi and other wireless Ethernet networks, and broadcasting and satellite services. There are many types of available statistics regarding access to ICTs and the ICT infrastructure including the percentage of households with computers and TVs, fixed telephone and mobile cellular subscription rates, Internet use, and fixed and mobile broadband subscriptions. Often, these are available at the country level, allowing grouping by region and level of development. Freely available interactive data on core ICT indicators at the country level of analysis can be found online at the International Telecommunications Union ICT Eye site (http://www.itu.int/net4/itu-d/icteye/) as well as at the World Bank data site (http://data.worldbank.org). In addition, the GSM Association provides a wide range of core statistics related to GSM networks, mobile phones and mobile applications in use around the world (https://mobiledevelopmentintelligence.com).

2.1 ICT Infrastructure Overview

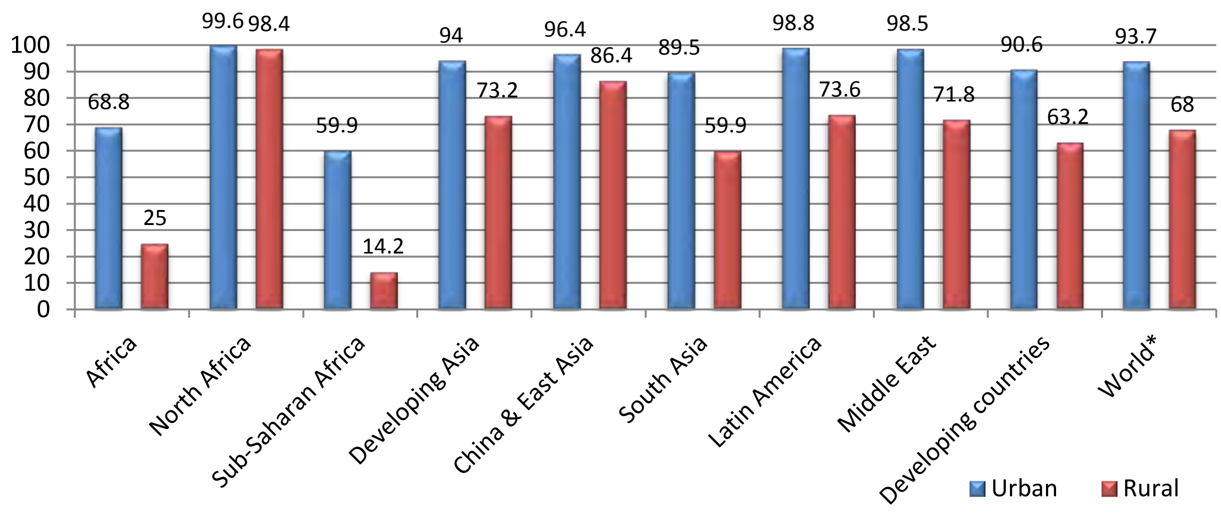
The use of ICTs is broadly constrained by the degree to which people have access to electricity, even for mobile phones and other battery powered devices which still must be charged to be used. According to the most recently available global electrification comparisons provided by the International Electricity Agency, which date from 2009, 80.5% of the world's population had access to electricity (see Figure 1), with slightly less than 75% of the population in developing countries having access. However, both regional and urban vs. rural differences are evident, especially in sub-Saharan Africa

[4] A growing movement now uses the broader ICTD acronym to represent ICT *and* Development (see http://ictlogy.net/20090829-icts-development-disciplines-and-acronyms/).

where in 2009, 59.9% of the urban population had access to electricity while only 14.2% of rural populations did. Even with some improvements likely since 2009, this low rural electrification rate in sub-Saharan Africa clearly limits the potential for many ICT applications, especially those based on computers and fixed network connections or even for the more power-hungry smartphones.

On a global basis, according to the most recent statistics provided by the International Telecommunications Union (ITU), mobile-cellular subscriptions have experienced explosive growth since 2001, rising from just 15.5 subscriptions per 100 inhabitants to near saturation at 96.2 subscriptions per 100 people in 2013 (see Figure 2). The ITU, in fact, reports that in 2013 there were 6.8 billion mobile subscriptions globally, which approaches the world's population, estimated at 7.1 billion (ITU, 2013). The number of Internet users increased as well in the same period, albeit less rapidly, rising from 8 per 100 in 2001 to 38.8 per 100 in 2013. During the same period, the number of fixed-line telephone subscriptions has actually started to decline, presumably due to the popularity of mobile phones as they increasingly replace fixed line subscriptions. Mobile broadband subscriptions have risen to nearly 30 per 100 people with the spread of 3G networks that support Internet Protocol (IP) traffic, enabling data services via cellphones. The number of fixed broadband subscriptions (i.e. cable modem, fiber, or DSL service) has grown but remains at under 10 per 100 people, although this measure is better approximated at a household level. Data on TV ownership is less readily available, with the ITU reporting that TV households increased from 74% globally in 2003 to 79% in 2010 (Figure 3).

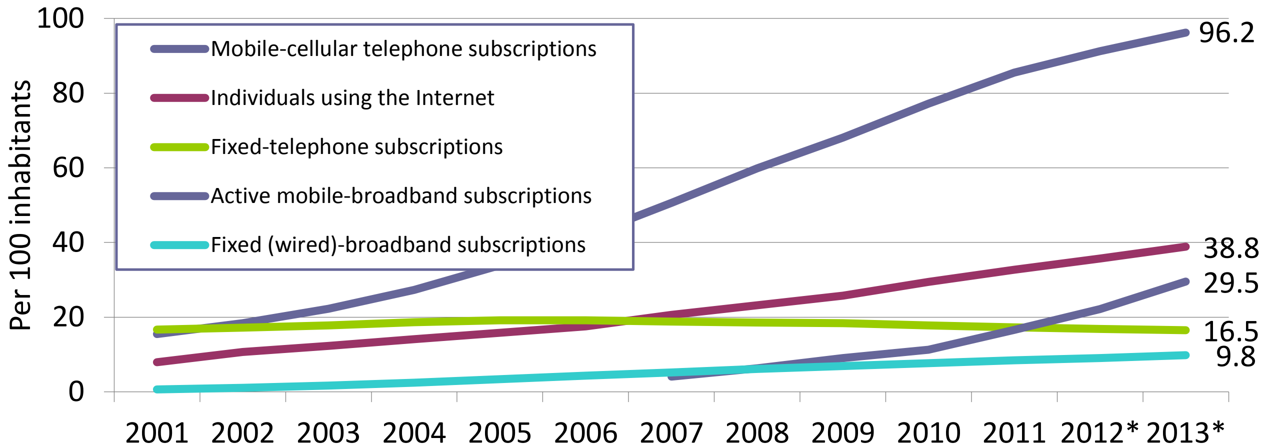
Figure 1: Urban vs. rural electricity access 2009 by world regions



Source: International Energy Association:
http://www.worldenergyoutlook.org/resources/energydevelopment/accesstoelectricity

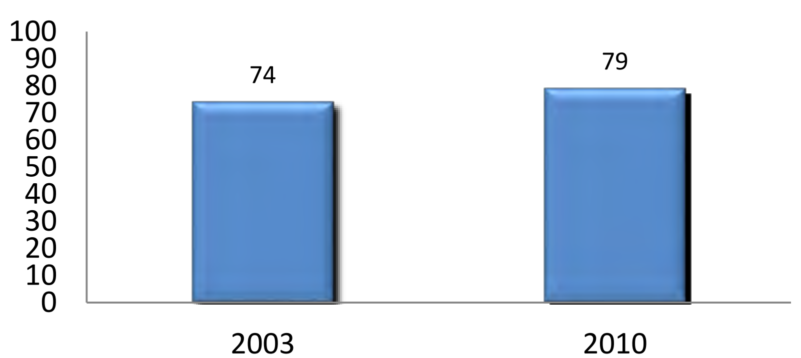
The challenges facing ICT4D projects become clearer when comparisons between the developed and developing world[5] are provided, as well as in the more detailed breakdowns that reveal region and country level differences. Of course, even at the country level of analysis, rural vs. urban differences are crucial, especially for agricultural applications of ICTs, but this data is not usually available on a widespread basis. Other access and use differences that influence the likelihood of successful applications of ICTs include differences by gender, which a number of researchers have observed as we show later, as well as by other demographic characteristics such as age and income.

Figure 2: Global ICT developments, 2001-2013



Source: ITU World Telecommunication/ICT Indicators Database.
Note: * estimate.

Figure 3: Percentage of households with a TV

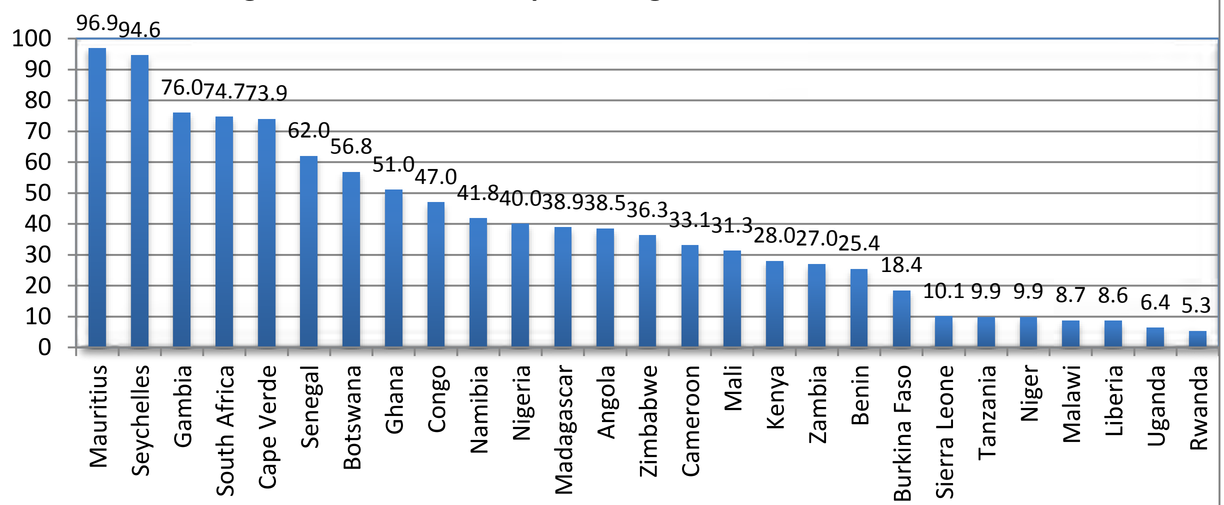


Source: ITU World Telecommunication /ICT Indicators database.

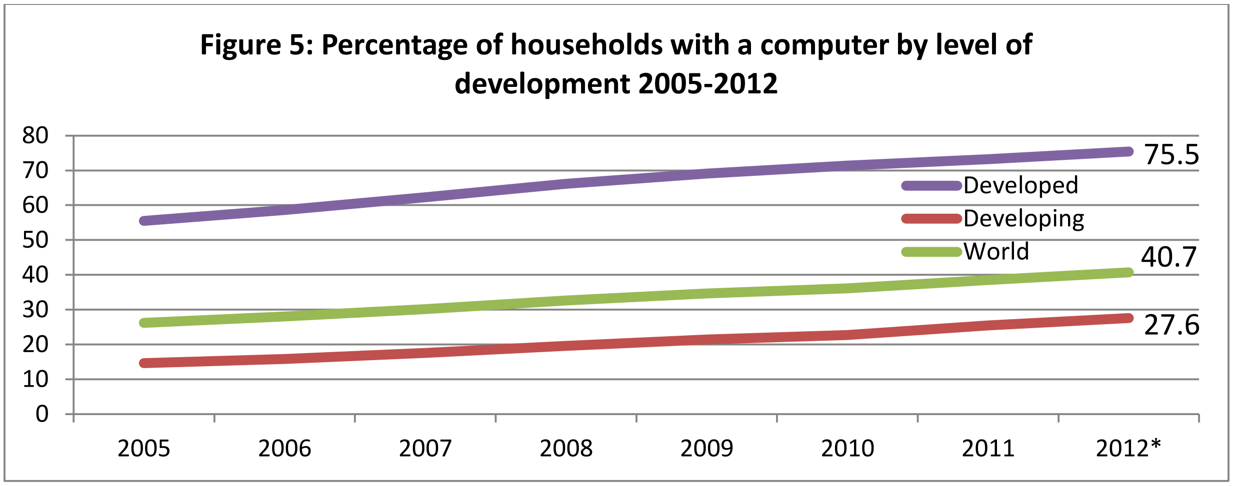
[5] The ITU developed/developing and region classifications are based on the UN M49. For a full list of which countries are included in each category, see: http://www.itu.int/ITU-D/ict/definitions/regions/index.html

Here we provide some broad-brush figures to illustrate the scope of the challenge. For example, data on TV ownership in the developing world is incomplete, with many countries not reporting this information. Based on the limited information available from the ITU, the proportion of TV households in developing countries for which this data is reported was 68.4% and just 38.9% for the 27 sub-Saharan African countries reporting this data. Moreover, the available TV household data for sub-Saharan Africa reveal how wide the country discrepancies can be even in the same region, ranging from a high of 96.9% in Mauritius to a low of 5.3% in Rwanda (see Figure 4). Also, while more than three quarters of the households in the developed world have a computer, this figure is only 27.6% in the developing world (see Figure 5) and stands at just 7.8% for African countries excluding the Arab States (Figure 6).

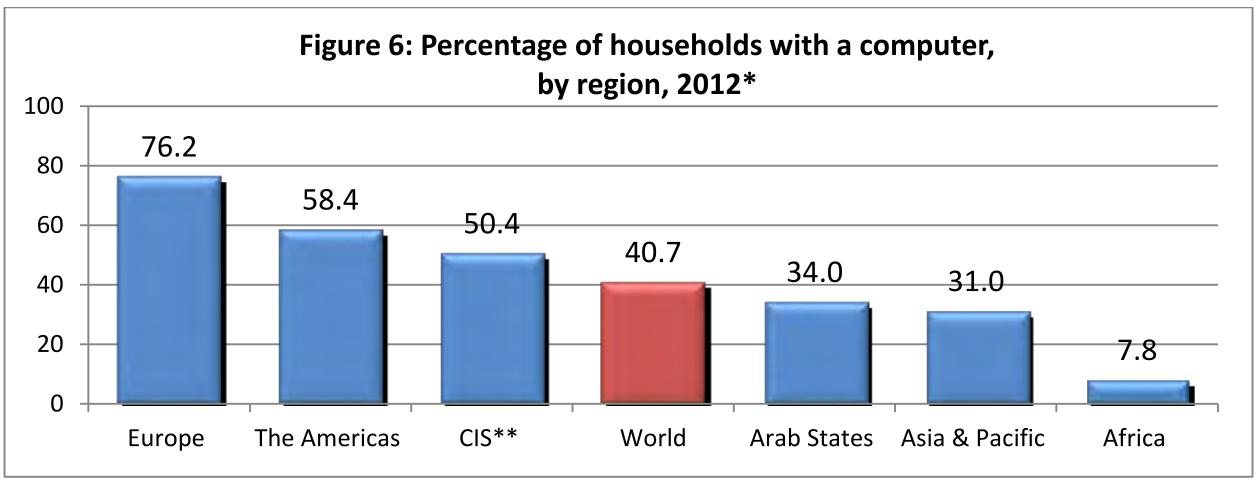
Figure 4: TV household percentage in Sub-Saharan Africa



Source: ITU World Telecommunication /ICT Indicators database.
Note: The dates of reporting ranges from 2008 to 2011.

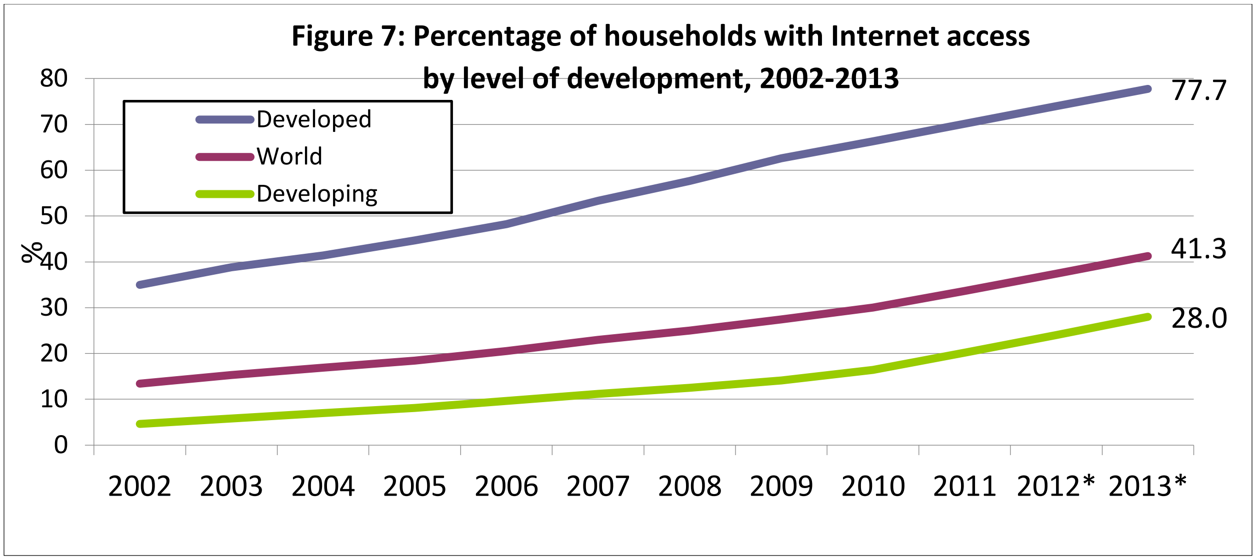


Source: ITU World Telecommunication /ICT Indicators database.
Note: * estimate.



Source: ITU World Telecommunication /ICT Indicators database
Note: * estimate * * Commonwealth of Independent States

Other core ICT indicators from the ITU show that while mobile and Internet access have grown substantially in developing regions over the past decade, disparities between developing and developed countries still remain (see Figures 7 -10). For example, the ITU estimates that as of 2013 the number of households with Internet access stands at 78% in the developed world and just 28% in the developing world, a statistic that parallels broadband access as it focuses on households where a computer is connected via broadband or dial-up connections (Figure 7). In Africa, exclusive of the Arab States, Internet access stands at just 6.7% (Figure 8).



Source: ITU World Telecommunication /ICT Indicators database.
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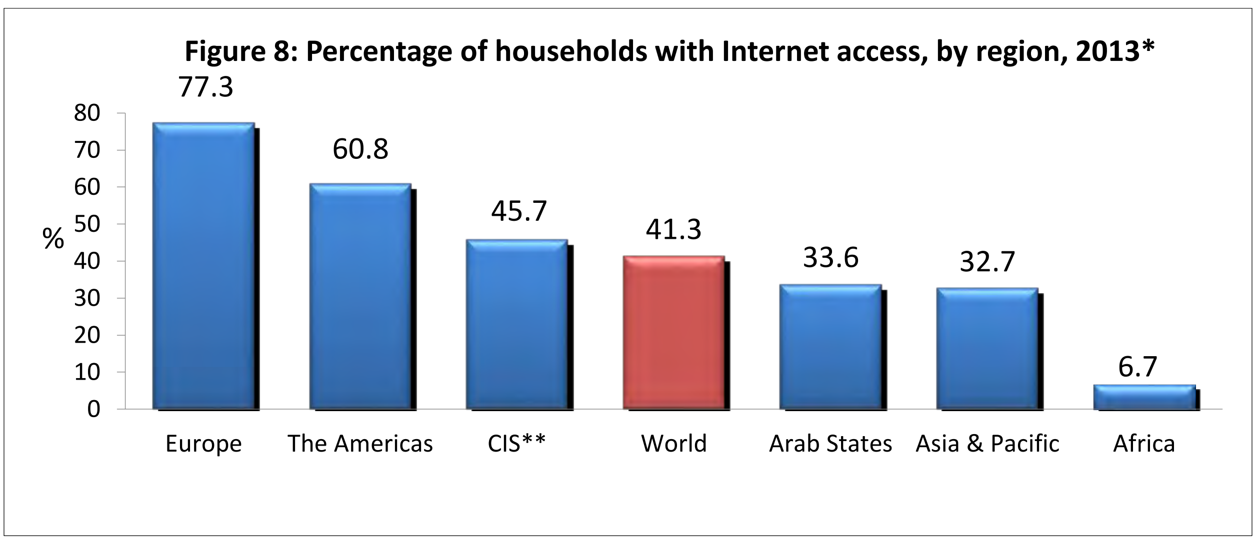
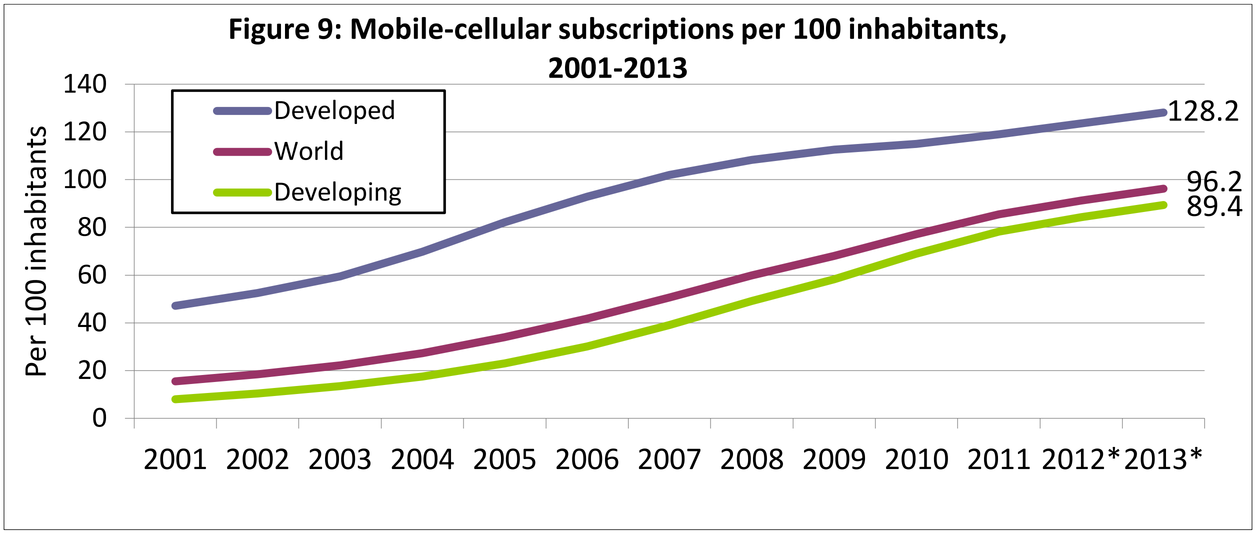


Source: ITU World Telecommunication /ICT Indicators database
Note: * estimate * * Commonwealth of Independent States

Mobile access presents a more positive picture with nearly 90 mobile subscriptions for every 100 people in developing regions of the world (Figure 9). The African region (exclusive of the Arab States which have quite high penetration), however, has a somewhat lower figure of 63.5% (Figure 10). Nonetheless, this is still represents a mobile for 2 of every 3 people, and the growth trajectory is remarkable, exceeding a

40% compound annual growth rate for the years 2000-2012 according to GSMA estimates (GSMA, 2012).



Source: ITU World Telecommunication /ICT Indicators database.
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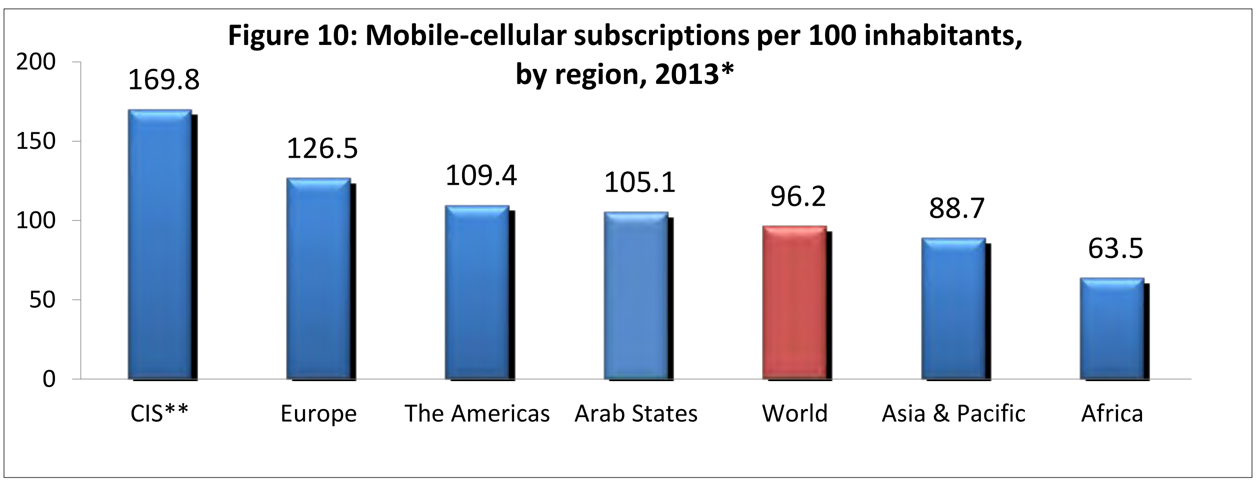
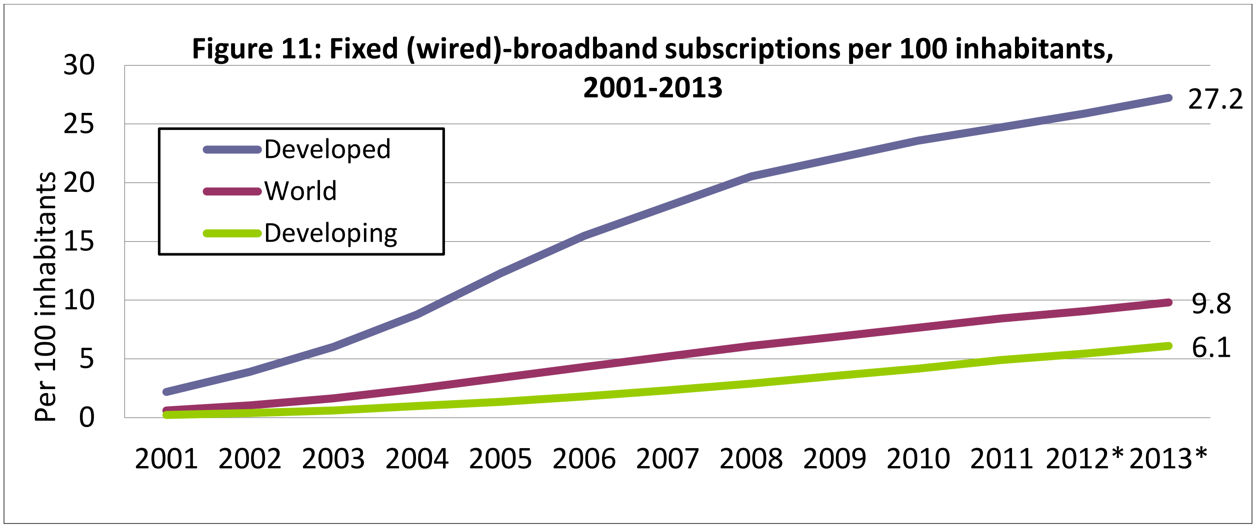


Source: ITU World Telecommunication /ICT Indicators database
Notes: * estimate, ** Commonwealth of Independent States.

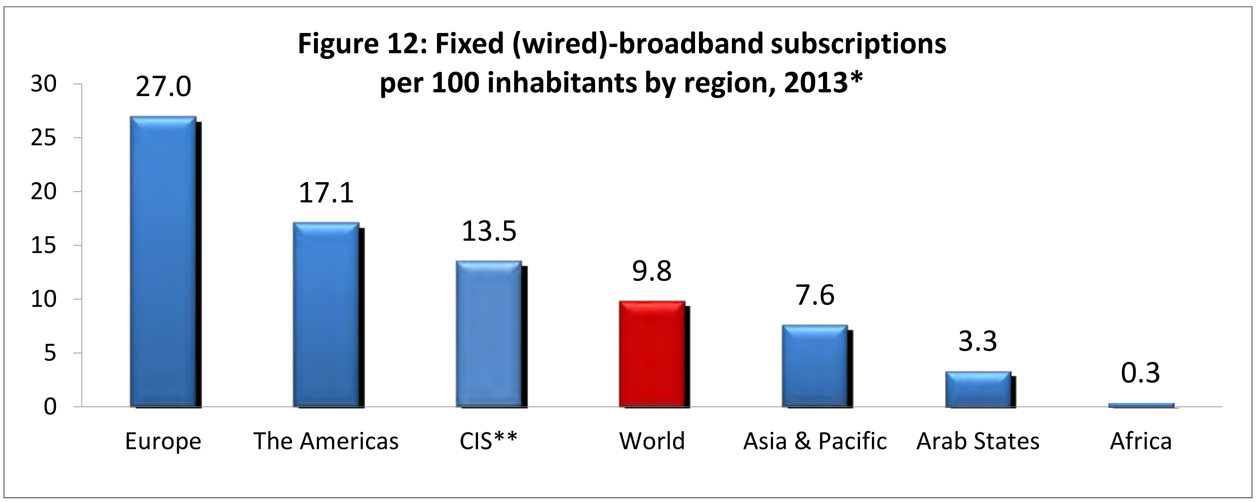
Many ICT4D researchers are convinced that because of the high penetration rate of mobiles in developing countries, designing information and services that rely on mobile devices is a better approach than designing for laptop or desktop computers (Heeks, 2008). Others debate this point, arguing that mobile devices are too limited in terms of screen size and bandwidth and that encouraging mobile in place of more capable gateways to the Internet will only increase rather than decrease the economic disadvantages of developing nations (Napoli & Obar, 2013). More realistically, the choice of appliance or access device should depend on the nature of the application (Best, 2010). It is also important to point out that ITU estimates of mobile subscription rates do not equal actual mobile phone ownership rates, primarily because many people, in order to capitalize on the price plans of competing operators, purchase multiple SIM cards, each of which shows up in the ITU data as a new subscription. Indeed, some people may own a SIM card but not a mobile phone, borrowing the phone (e.g. from a spouse) and installing their own SIM card when having to make a call. Hence, the extent to which any individual has access to mobile services both under- and overestimates actual mobile access. The fact that many people purchase multiple SIM cards and, in some cases, multiple handsets, explains why there are more than 100 subscriptions per 100 people in the developed world. Underestimation of mobile phone *access*, however, also is possible due to the fact that in the developing world, it is not uncommon for people to share a mobile phone (Aker & Mbiti, 2010).

Masked by Internet access statistics, however, are differences in the quality of Internet connections. In the world's richest countries, high quality Internet access via wired broadband connections has become more common (27 subscriptions per 100 people, see Figure 11), but this remains a rarity in the developed world, with fewer than 6.1 subscriptions per 100 people (see Figure 12) and a mere 0.3 per 100 people in Africa (Figure 12).[6] Additionally, ITU 2013 data reveal that even where connections are considered to be broadband, the differences in speed of connections as well as the prices of connections are significant. For example, less than 10% of the African broadband connections reach 2 Mbps while 90% or more of the broadband connections in many developed countries in Asia and Europe exceed this speed. Moreover, as of 2012, fixed broadband prices represented only 1.7% of monthly income in developed countries while accounting for 30.1% of average monthly incomes in developing countries (ITU, 2013).

[6] As noted earlier, a more appropriate measure would be households with a fixed broadband connection, as this is not typically an individual purchase.



Source: ITU World Telecommunication /ICT Indicators database.
Note: * estimate.



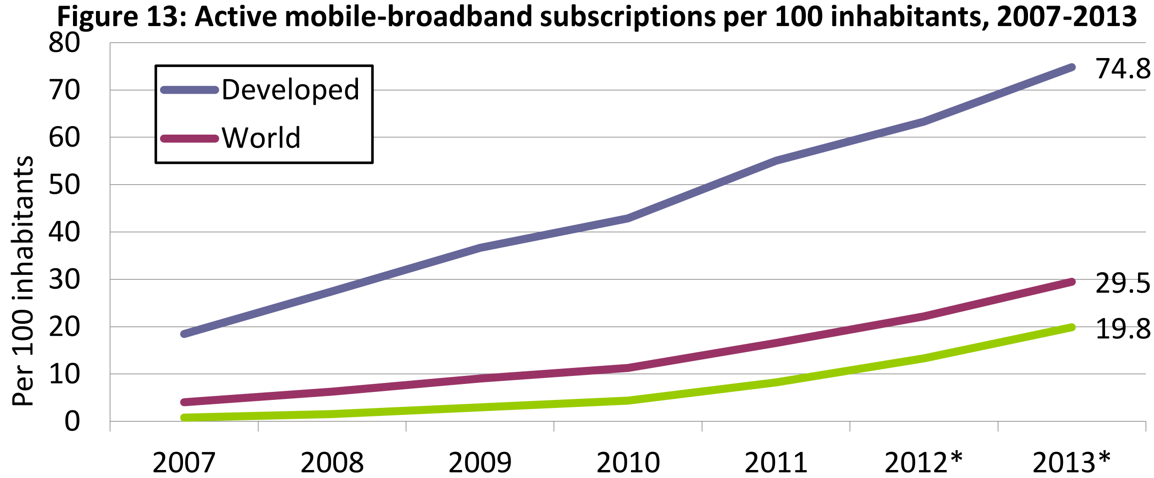
Source: ITU World Telecommunication /ICT Indicators database
Note: * estimate * * Commonwealth of Independent States

A more likely approach to the provision of access to Internet-based information and services in developing regions is via mobile broadband, given the widespread coverage of 3G networks. A recent Ericsson study, for example, estimates that approximately 55% of the world's population had access to true third generation (3G) mobile cellular networks at the end of 2012 (Ericsson, 2013).[7] Data services on these networks are

[7] By "true 3g", the report considers WCDMA technology as the minimum, with the earlier GSM/EDGE technology considered a pre-3G service even though data services are still possible. If EDGE networks are included, the global population coverage rises to 85% in the Ericsson estimates.

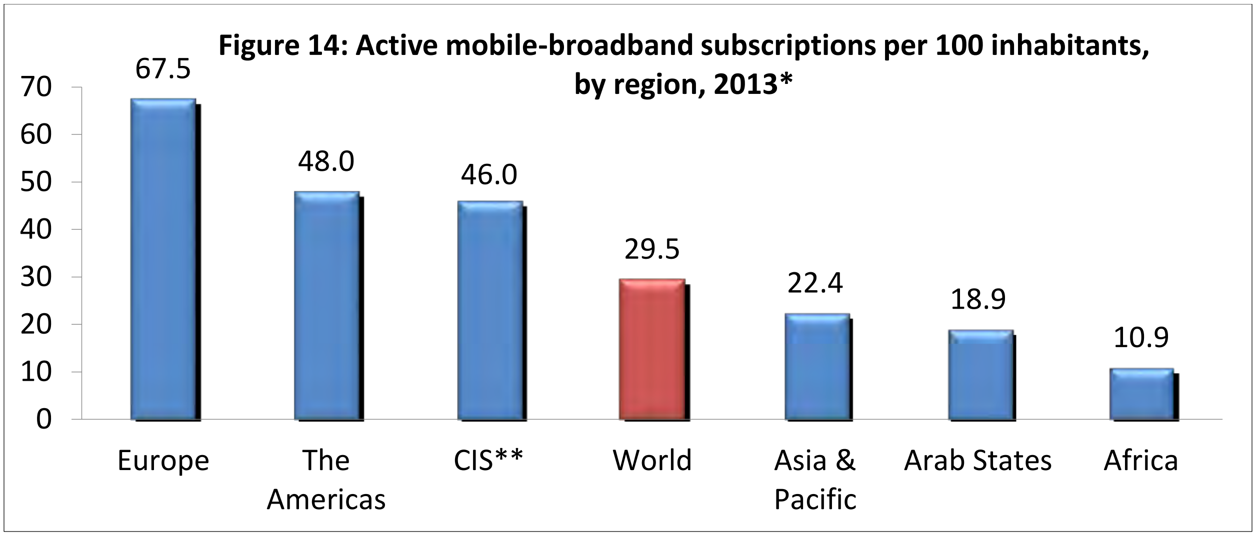
growing much faster than voice services and offer an alternative to traditional Internet services. Indeed, in many countries, 3G modems that can plug into USB ports on laptops, and desktop computers represent a popular way for computer users to connect to the Internet (ABI Research, 2011). The ITU estimates that active mobile-broadband subscriptions have grown to 74.8 for every 100 persons in the developed world, while reaching nearly 20 people out of every 100 in the developing world (see Figure 13).[8] This figure drops to an estimated 10.9 out of 100 people for 2013 in the Africa region (excluding the Arab States, see Figure 14). Estimates of the extent of the population covered by 3G networks in individual countries is available from the GSM Association (https://gsmaintelligence.com), and can range from virtually no 3G coverage in such countries as Benin, Burkina Faso, Cameroon, Cote d'Ivoire, the Democratic Republic of Congo, Eritrea, and Gabon, to 26% of the population covered in South Africa. In selected East African countries, these percentages include 21% in Rwanda, 17% in Kenya, 14% in Tanzania, 13% in Ethiopia, 12% in Mozambique, 4% in Uganda and Malawi, and 2% in Zambia.

Figure 13: Active mobile-broadband subscriptions per 100 inhabitants, 2007-2013



Source: ITU World Telecommunication /ICT Indicators database
Note: * estimate

[8] The ITU considers an "active mobile-broadband subscription" to be one that allows downloads of 256K or higher, can access the Internet via an HTTP connection, and has been used to download data via IP in the past 3 months (see http://www.itu.int/ITU-D/ict/material/TelecomICT_Indicators_Definition_March2010_for_web.pdf).



Source: ITU World Telecommunication /ICT Indicators database
Note: * estimate * * Commonwealth of Independent States

2.2 Summary

This brief overview of the status of the ICT infrastructure highlights that while there is increasing access to advanced ICTs throughout the developing world, gaps remain significant. It is clear that in order to provide value-added information and services to small scale participants in the agricultural sector, multiple strategies are required, including use of traditional media like television and radio as well as through mobiles. Internet connected computers may play a role in situations where people are able to access local cyber cafes or telecenters, but home access is unlikely for the near future. Smartphones, with their larger screens and ability to provide multimedia information, are being adopted rapidly throughout the world and can be useful tools for providing a wide range of services in support of agriculture.[9] However, these types of mobile phones are only just beginning to diffuse in developing regions and little reliable public data on smartphone penetration in developing countries is available.[10] Moreover, smartphone prices are still rather high, they use more electricity, and they impose higher costs due to the need for additional pre-paid credits to access the Internet. Hence, voice and SMS/text applications will continue to be important for the near future for ICT for agricultural services. However, as mid-range phones (often called "feature phones") become more capable by incorporating application programming interfaces (APIs), richer applications are becoming more affordable.

[9] In the US and other developed areas, many "precision agriculture" applications, which gather and analyze data, and recommend farming practices from location-based irrigation to fertilization to pesticide application, are now available for smartphones (e.g. see http://www.croplife.com/article/23035/20-best-mobile-apps-for-agriculture).
[10] A recent Techcrunch article found estimates of smartphone penetration of between 3 and 17% in sub-Saharan Africa (see http://techcrunch.com/2012/06/09/feature-phones-are-not-the-future/).

3. Overview of ICT in Agriculture Applications for Developing Countries

Given the dominant role of agriculture in the economy of developing countries, it is not surprising that many ICT4D projects target the agriculture sector, in addition to those focusing on health, education, financial services, and other core development initiatives. Several recent volumes published by the World Bank and other development-oriented organizations have provided a rich set of resources documenting opportunities to apply ICTs, and especially mobiles, in support of activities across the entire agricultural value chain, including *eTransform Africa* (Yonazi, Kelly, Halewood, & Blackman, 2012), the *ICT in Africa eSourcebook* (World Bank, 2011), *Information and Communication Technology for Development: Maximizing Mobile* (World Bank, 2012), *The Innovative Use of Mobile Applications in East Africa* (Hellström, 2010), and the *Inventory of Innovative Farmer Advisory Services Using Information Communication Technologies* (FARA (Forum for Agricultural Research in Africa), 2009). These reports and the vast scholarly work on ICT4D outline the basic ways that ICTs can be harnessed to support the work of smallholder farmers. This section provides a broad overview of the types of information and communication problems that ICT4D solutions aim to address as well as the types of ICT4D systems that have been developed. Brief introductions to example projects that have received some attention in major ICT4D publications are provided.

3.1 Assessing the information needs of farmers

Prior work has contributed a variety of useful frameworks for understanding the information needs of farmers from which potential applications can be derived (Chapman & Slaymaker, 2002; Mittal, Gandhi, & Tripathi, 2010). Mittal et al (2010) conducted a national survey of farmers in India, identifying three broad categories of information needed by farmers:

- fundamental information on farming techniques, which they termed *know-how*
- *contextual* information such as the current state of the weather and the types of crops that work well in the particular local area
- *market* information such as the prices of inputs and commodities, demand information, and transport and logistics information

Additionally, these three categories of information are needed at varying times over the agricultural life-cycle, which extends through the following six phases, according to Mittal et al (2010):

- crop planning – e.g. information on crop yields and seed varieties, as well as information on the local context
- buying seeds and other inputs – e.g. prices of seeds and other inputs

- planting – e.g. best time to plant given weather conditions
- growing – e.g. best techniques for applying fertilizer
- harvesting, packing and storing – e.g. best time to harvest given weather conditions
- selling – e.g. finding best prices, transport options

The most critical types of information, according to the farmers interviewed in the Mittal et al (2010) study, were weather, plant protection through disease and pest control, seed information, and market prices.

An earlier framework from Chapman and Slaymaker (2002) also distinguishes between core farming knowledge (termed Type A information), which emphasizes the need for training and education aimed at long-term capacity building, and local contextual knowledge (Type B), which emphasizes the need for short-term decision-making and, therefore, frequent updating. Chapman and Slaymaker (2002) further discuss five types of *livelihood assets* or factors of production that rural populations can possess, including human capital (knowledge), financial capital, social capital (benefits derived from social networks), natural capital (e.g. land), and physical capital (e.g. equipment). They argue that both Type A and Type B information are essential to guide decision-making and increase the productivity of these forms of capital and describe ways that open access, community models such as rural telecenters and community knowledge centers can provide needed information.

In the Mittal et al (2010) report, the authors focus on mobile phone based approaches, highlighting two of the more prominent services available in India: the Reuters Market Light (RML) service, which provides market price, weather, and other crop information via SMS/text messaging to subscribers, and the IFFCO Kisan Sanchar Limited (IKSL) service, which provides a range of advisory information via voice messages. These services illustrate the transition away from a reliance on more centralized ICT approaches such as community knowledge centers identified in Chapman and Slaymaker (2002) toward a new focus on more decentralized methods capitalizing on the rapid diffusion of personal mobile phones among the rural poor. Most of the new services relying on mobiles have relied on SMS due to its low cost and the ability it gives users to store and review information.

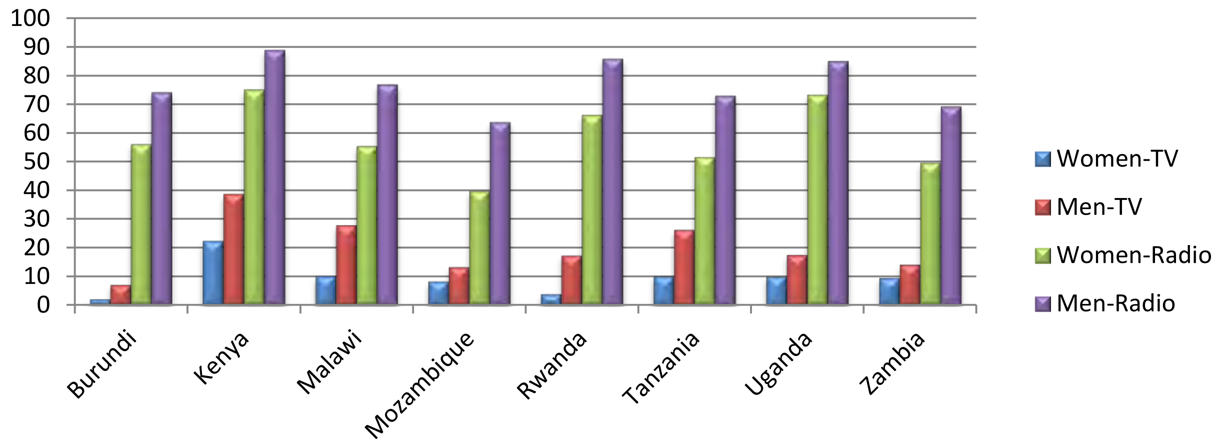
3.2 Examples of services that address agricultural sector information needs

An enormous variety of ICT-driven services addressing agricultural sector needs have been deployed in developing regions, including both commercial and not-for-profit projects such as those run by NGOs. In addition to the World Bank and other reports cited above at the start of this section, individual profiles of dozens of ICT projects aimed at enhancing agriculture in developing countries are provided by USAID (https://communities.usaidallnet.gov/ictforag/documents). Moreover, the *Beyond*

Market Prices project at UC Berkeley maintains an online database that currently lists 216 ICT for agriculture projects (http://markets.ischool.berkeley.edu/projects/).

One way to differentiate the many services is by the primary communications channel used to connect service providers to end users (e.g. smallholder farmers). For example, a number of services focuses on traditional media, and especially radio, as the conduit to farmers given the relatively higher penetration of radios in rural areas. As shown in the chart depicting data from household surveys from USAID (see Figure 15), although women consistently report lower levels of both TV viewing and radio listening than men, overall rural radio listening is substantially higher than rural television viewing for both men and women in several East African countries.

Figure 15: Proportion of Men and Women Who Watch TV and Listen to Radio in Rural Areas in Selected East African Countries



Source: USAID Demographic and Household Surveys (http://www.measuredhs.com). Survey dates: 2011: Mozambique, Uganda; 2010: Burundi, Malawi, Rwanda, Tanzania; 2008-2009: Kenya; 2007: Zambia

3.2.1 Radio and TV-based ICT for Agriculture Services

Given the greater use of radio in rural households where farming is the dominant economic activity, it is not surprising that many development initiatives rely on radio programming. One Canadian-based organization, Farm Radio International (FRI) (www.farmradio.org), provides support for over 400 radio broadcasters in 38 different African countries to help develop programming aimed at improving the lives of small farmers. An important lesson from their years of experience working with African broadcasters is that radio programs that involve farmers in a more participatory experience are more likely to have an impact. Involving farmers in programs helps to make the content more relevant and encourages greater local interest. FRI is one of many partners in an initiative in several East African countries, including Tanzania, Kenya, Malawi, and Uganda, called Farmer Voice Radio (FVR) (www.farmervoice.org) that builds on this participatory concept with local community radio stations. Community and participatory radio is being heralded as a way to extend the reach of agricultural extension agents, who are simply too few in number to be able to have in-person contacts with individual farmers (Sanga, Kalungwizi, & Msuya, 2013). Due to innovations in radio broadcasting technology, such as the use of low power transmitters, local community stations are more affordable now than in the past. Moreover, the integration of radio with mobile phones, permitting voice and text interaction with listeners, has enhanced participation (Harrod & Jamsen, 2011). It should be noted, however, that even radios can be a significant cost to the poorest of farmers, both in terms of the device itself, and the costs of batteries needed to power radios in areas with no electricity.

The lower access to television, especially in rural areas, has limited its use for ICT for agriculture projects, but there are recent examples of the creative use of video, especially when integrated with other ICTs. The participatory strategies that rely on integration with the Internet and mobile devices, as well as the use of farmers in the video production are also evident in such video-based activities as the popular Shamba Shape Up program produced by Mediae in Kenya (www.shambashapeup.com), the Ruka Juu program produced by FeminaHIP in Tanzania (rukajuu.feminahip.or.tz), and the Digital Green project originally launched by Microsoft's Technology for Emerging Markets group in India and now active in several countries in Africa (www.digitalgreen.org).

Shamba Shape Up is a popular farm makeover reality show created by the Mediae Company in Kenya aired in both English and Swahili (USAID, 2013a). According to their web site[11], it reached nearly 7 million viewers by the end of their first season and anticipates the audience size growing to 11 million in seasons 2 and 3 as they expand to Tanzania and Uganda. Each episode involves agricultural experts visiting a real family farm and demonstrating how to improve production practices with practical solutions. The integration of mobile phones and the Internet is clearly evident in that viewers can send SMS text messages following each episode to receive a flyer with a summary of the information presented; all of the episodes are posted on the show's web site for viewing, and the program creators maintain an active Facebook page that currently has over 11,000 "likes".

A similar "edutainment" approach to educating farmers in Tanzania called Ruka Juu (Jump Up in Swahili) has been developed by the Femina HIP multimedia platform and civil society organization in Dar es Salaam.[12] Femina HIP claims to reach over 11 million Tanzanians across all of their products. The Ruka Juu show targets Tanzanian youth and also uses a reality show format where 6 young Tanzanian farmers (3 men and 3 women) selected from rural villages compete against each other in farming challenges to see who will win a plot of land for their own farm. Each episode involves

[11] http://www.shambashapeup.com/making-of-shamba-shape-up
[12] http://www.feminahip.or.tz/products/ruka-juu-na-fema-tv-show.html

experts mentoring the young farmers as they solve the challenges related to running their farms. Viewers interact and vote through SMS text messaging.

A final example of the creative use of video is the Digital Green project, which was launched in 2006 in India and has been shown to increase the adoption of new agricultural practices among small and marginalized farmers (Gandhi, Veeraraghavan, Toyama, & Ramprasad, 2009). According to a recent USAID profile, it reaches over 1500 villages and 100,000 small-scale farmers in remote areas of India with short instructional videos featuring local farmers interacting with agricultural experts (USAID, 2012a). Video segments are produced in a participatory production process in the villages using pocket video cameras and shown locally with pico projectors[13]. Community feedback is also encouraged using phones with an interactive voice response (IVR) platform. Although begun as a project by Microsoft's Technologies for Emerging Markets group in India, Digital Green is now an NGO supported by Gates and other donors and is expanding into several countries in Africa.

As these examples illustrate, today's versions of radio and television-based ICT4D projects are aimed at augmenting agricultural extension services. They depart from traditional mass media programming by emphasizing participatory approaches featuring local farmers in the content, and even involving them as producers of content. In addition, these projects make full use of multiple channels, capitalizing on the two-way communication capabilities of mobile phones and the web to make content more engaging, interactive, and viewable on demand.

3.2.2 Mobile applications for agriculture

The explosive growth of mobile phones throughout the developing world has led to a proliferation of projects and services that make use of these devices. There are many different ways that ICT for agriculture mobile applications could be classified. Donovan (Donovan, 2011) provides two broad approaches: a more generalized classification of mobile applications aimed at improving livelihoods, and a more specific one aimed strictly at agricultural settings. As an example of the former approach, Donner (Donner, 2009) distinguishes between six categories of service, including mediated agricultural extension, market information systems, virtual marketplaces, comprehensive services, financial services, and direct livelihood support.

To illustrate the latter approach, Hellström (2010) emphasizes four specific types of agricultural services that are needed by smallholder farmers:

- education and awareness: services that connect farmers to extension agents via mobile

[13] Pico projectors are very small sized, hand-held projectors, sometimes built into mobile phones, that are capable of projecting images onto nearby surfaces. Often called pocket or mobile projectors, these are ideal for displaying stored images and video out in the field where room-based projectors and electricity are simply not available.

- commodity prices and market information: services that provide up-to-date prices
- data collection: services that use mobiles to collect and aggregate data from geographic regions
- pest and disease outbreak warnings and tracking: services that use mobiles to send and receive data on outbreaks

More recently, a World Bank publication (World Bank, 2012) on mobile applications for development describes four types of agriculture-specific applications in use, drawing from a 2011 Vodafone report (Vodafone, 2011). These include:

- improving access to financial services, which can include platforms for payment services, insurance, and lending services
- providing agricultural information including prices, weather, and information on agricultural techniques
- improving data visibility in the supply chain, including logistics, traceability and tracking systems, and supplier and distribution management support.
- enhancing access to markets such as platforms for trading, tendering, and bartering

As an effort to integrate these various approaches, the four categories depicted in Table 1 summarize the various types of existing mobile phone-based agricultural services, recognizing that many services attempt to address multiple functions.

Table 1: Types of Mobile Phone-based Agricultural Services

Type	Description	Selected Examples
Farmer advisory and information services	These services focus on providing agricultural information to farmers, often in two-way interactions with extension agents and other experts. They can include basic information on crops and techniques, weather, disease and other types of alerts, as well as responses to questions posed by farmers. They are often integrated with comprehensive web sites (e.g. NAFIS in Kenya), and mobile services are generally voice-based.	• M-Kilimo Kenya Farmers Helpline (www.m-kilimo.com) • National Farmers Information Service (NAFIS) (www.nafis.co.ke) • CocoaLink (worldcocoafoundation.org /cocoalink)
Market information services	These services seek to address information asymmetries between buyers and sellers in the agricultural value chain, and notably seek to improve the bargaining power of small farmers in their interactions with traders who come to the farm gate and acquire harvests at below market prices.	• Reuters Market Lite (RML) (www.reutersmarketlight.com) • Esoko (www.esoko.com) • Kenya Agricultural Commodities Exchange (www.kacekenya.co.ke)

Type	Description	Selected Examples
	They usually provide information via text message on current market prices of various crops on request. More sophisticated services will also provide buyer-seller matching and group selling services for smallholder farmers, as well as "push" information related to farming. Some of these services (e.g. the Kenya Agricultural Commodities Exchange and Esoko) also integrate with the Internet and/or traditional media like radio to provide a rich suite of services.	• M-Farm (mfarm.co.ke)
Financial services	These services broadly rely on mobile platforms to offer people the ability to make and receive payments via their mobile phones, using a widely distributed retail network of kiosks staffed by agents that reaches into rural villages where traditional banking organizations do not. These are generally controlled by mobile operators such as Safaricom and can further be used to provide other financial services such as micro-insurance and micro-lending.	• M-PESA (www.safaricom.co.ke) • Airtel Money (www.airtel.in/money) • Kilimo Salama (kilimosalama.wordpress.com) • M-Shwari (www.safaricom.co.ke/personal/m-pesa/m-shwari)
Decision support services	A range of projects and services use mobile devices to collect information from farmers and then provide prescriptive information to support decision making to improve farm yields. Farmers might provide information about crop height or livestock weight, for example, which when combined with other data (location, date, weather patterns, etc.) yield recommendations for watering, fertilization, feeding, etc. In more developed contexts, numerous smartphone applications now exist to offer such "precision agriculture" services[14], but services also exist for basic feature phones.	• iCow (www.icow.co.ke) • Nutrient Manager for Rice (NMRice) (see irri.org for details)

Mobile **farmer information and advisory services** attempt to augment the vastly understaffed extension services in developing countries. As an example, the M-Kilimo Kenya Farmers' Helpline began in 2009 with a grant from the Rockefeller Foundation through the GSMA Development Fund's mAgri initiative (USAID, 2011a). Farmers can

[14] See http://www.croplife.com/article/23035/20-best-mobile-apps-for-agriculture for examples.

call into a call center operated by Kencall in order to receive real-time answers to questions they might have or receive a call-back within 24 hours. The call center is staffed by agricultural experts supported by an ever-growing content management system. The service is now accessible as well to agricultural extension agents (see www.m-kilimo.com/what-we-do). Although there are no surcharges for use of the service, farmers are responsible for the airtime charges of their call.

Market information services attempt to address the high transaction costs faced by farmers, especially search costs involved with finding out the current prices of commodities they might wish to sell at regional markets. Prior to having mobile phones, the only way that farmers could learn prices would be to travel personally to a market. In the absence of such information, traders could easily exploit farmers at the farm gate to obtain harvested goods at well-below market prices. A current example of a mobile service addressing this issue is MFarm, which allows farmers to obtain market prices in the five largest markets in Kenya via SMS text (USAID, 2012b). Farmers register with the service, and then can send a text request to a short code requesting the price of one of 42 different goods from one of the five markets (formatted as price crop market). They pay 1 Kenyan shilling ($.01 US) for each text. MFarm hires people to visit the five markets on a daily basis to obtain at least five samples of prices from five different sellers. An average daily price is then calculated and made available to users. Farmers can also join together to sell their crops in bulk to larger buyers, and can purchase farm inputs in bulk from suppliers (USAID, 2012b).

M-PESA is the most widely used mobile **financial service** in east Africa, with over 17 million customers according to a 2013 Safaricom presentation.[15] It is a service of Safaricom, the largest mobile operator in Kenya. Customers who register for M-PESA accounts can send and receive funds and pay bills via SMS. They can add money to their M-PESA account and receive cash from funds that have been sent to them through a network of local agents staffing Safaricom kiosks. As of 2013, there were more than 65,000 M-PESA agents, making kiosks widely available even in small villages. Hence, rural farmers who live in areas without bank branches can have access to financial services, while development organizations can use M-PESA to offer microloans to small farmers to help pay for farm inputs (World Bank, 2011). Farmers can then use M-PESA to make it easier to repay the loans without having to carry cash. Safaricom levies small fees on M-PESA transactions, which generate significant revenue for the company.

One of the best examples of a **decision support** system that uses mobile phones is the Nutrient Manager for Rice system in use in several southeast Asian countries (USAID, 2012c). Developed by the International Rice Research Institute (IRRI) and the Philippine Department of Agriculture, *NMRiceMobile* allows farmers to receive fertilizer

[15] http://www.safaricom.co.ke/images/Downloads/Resources_Downloads/FY_2013_Results_Presentation.pdf

recommendations customized to their local rice field via their mobile phone using what is called *site-specific nutrient management* (Ferrer, 2010). Rice farmers answer a series of questions about their field using interactive voice response, and then receive a text message with specific instructions on when and how much fertilizer to apply.

Many sophisticated decision support and precision applications are possible and have been implemented in developed countries with great success. The ICT in Agriculture Sourcebook provides a number of examples where sensor networks, GPS, satellites, aerial images, and RFID can be harnessed to improve the productivity of farms, including addressing questions pertaining to the quality of the soil and land preparation needs, questions about seeds and planting, fertilizer use, harvest dates, and livestock tracking and management (Pehu, Belden, Majumdar, & Jantunen, 2011). In many cases, these types of applications apply more to larger farms (e.g. where mechanization is feasible), but as costs decrease, there may eventually be applications built into lower cost phones that are within the reach of smallholder farmers.

3.2.3 ICTs to Increase Efficiencies in the Agricultural Supply Chain

One area of focus for the use of a range of ICTs, including laptop and desktop computers as well as mobiles, is to increase efficiency in agricultural supply chains (Sen and Choudhary, 2011, USAID, 2010). Increasingly, as computers and mobiles become more widely available, there are more opportunities to connect smallholder farmers to the supply chain information systems of larger agribusiness companies. Often, these systems are introduced without a great deal of fanfare and, hence, might be called "quiet" use of ICTs.[16] In many cases, such quiet supply chain applications involve what many Western companies would consider to be routine use of ICTs – e.g. spreadsheets, GPS, and simple text messaging – to improve coordination with local farmers. For example, the Projet Croissance Economique in Senegal involves the use of spreadsheets, distributed by Dropbox, that contain data on the exact GPS coordinates of a farmer's plot, planting dates, and crop varieties. Farmers can use the resulting maps derived from the GPS coordinates to know the exact size of their fields, enabling more precise orders for inputs that can save money. Additionally, mills can monitor harvest information to improve payouts to farmers (USAID, 2012e). Another example from our own field work in Kenya can be found with the Mumias Sugar Company, which employs a computer system at their weighing station to track the weight of each farmer's harvest in order to affect proper credit, and further uses farmers' mobile phones and the M-Pesa system to offer advance payment on harvests to their contract farmers. Supply chain information systems not only reduce transaction costs, making it possible to coordinate among large numbers of smallholder farmers, they also provide traceability capability that may be demanded by international markets.

[16] Per email exchange with Judith Payne, ebusiness advisor, USAID

3.2.4 Using ICTs to Support Intermediaries and Collective Action

Recognizing that there are still many people – and especially women - without mobile devices, that most mobiles are not smartphones and, hence, have limited data features, and that some local input is useful to place information in a proper context, some aid organizations instead work through local intermediaries rather than attempt to design services that directly reach smallholder farmers. One well known example of this approach is the Grameen Foundation's Community Knowledge Worker (CKW) program based in Uganda (USAID, 2011b). Trusted community members receive agricultural training and a smartphone through the CKW program. The smartphone has access to an extensive agricultural database containing more than 35,000 real-time tips on 35 crops and 7 livestock animals as well as weather, market, and transportation data. Much information is available both in local memory on the phone and through the network, enabling the CKW to provide free agricultural information and advice to smallholder farmers in their village regardless of cell network signal quality. The CKW can also collect information from local farmers, helping the foundation identify disease and pest outbreaks. According to the CKW program dashboard (grameenfoundation.force.com/ckw/Dashboard), nearly 200,000 farmers have been reached with more than 1100 CKWs.

The ability to engage in collective action to improve farm outcomes is becoming more feasible due to the spread of mobile devices connected to data networks. An example highlighted in Pehu et al (2011) is the Digital Early Warning Network, a part of the Great Lakes Cassava Initiative in east Africa. Farmers trained to recognize symptoms of cassava mosaic disease and cassava brown streak disease send out monthly text messages to researchers about disease incidence and receive disease control advice in return. Farmers are organized into groups of 60, and if more than 10 percent report the disease, experts visit the group to provide assistance. This type of crowdsourcing can help researchers gather critical data on a wide range of agricultural topics.

3.3 Summary

The mobile applications highlighted here collectively illustrate an effort to reach out more directly to individual farmers with "pull" services designed to support on demand information access, create more market transparency, and provide them with financial and decision support tools designed to increase productivity. They illustrate as well how information sharing made possible by mobile devices facilitates collective action. One concern voiced by analysts is the extent to which the many mobile ICT for agriculture services aimed at small farmers can be self-sustaining (USAID, 2013b). Some depend on the continuing support of aid organizations, while others build in membership or transaction fees that may make it harder to afford for the very group that these services seek to support – smallholder farmers who are often largely operating on a subsistence level. In some cases, corporate sponsorships that function much like advertising have been used to bring down the cost of such fees. MFarm, for example, concludes each price quote with a Samsung sponsorship message (Wyche & Steinfield, 2013). These can be confusing, however, and reduces the number of characters available for agricultural information to farmers.

4. Recent Outcomes Research on ICTs in Agriculture

Assessing the impacts of using ICTs to address the needs of smallholder farmers is difficult due to the many factors that can influence outcomes. Although many projects do provide some form of evaluation, these often measure intermediate processes such as the number of farmers who use the ICT in question or the frequency of use of services rather than longer-term economic benefits. To some extent, ICT4D projects have been criticized in the past for considering use of the ICT tools themselves as the development outcome, rather than as a means to an end (Heeks, 2008). This may also be due to the fact that projects are often at too early a stage to have had a chance at creating real impact, or because they lack a sustainable and scalable business model, by remaining too localized or ending too soon (USAID, 2013b). The local, social, and cultural context in which ICT tools are embedded also vary considerably, making it even more difficult to assess the broader impacts of mobiles, Internet access and other ICT tools on farmers' livelihoods (Burrell & Oreglia, 2013; Burrell, 2010).

Among the most common services provided in ICT projects aimed at smallholder farmers are those providing market price information (USAID, 2013b), and in this area, there has been recent investigation into longer-term economic benefits. As noted earlier, these services focus on reducing farmers' search costs, reducing information asymmetries, and strengthening their bargaining power with middlemen. Prior work has found that farmers and fisherman have experienced reductions in search costs related to prices due to use of mobile phones, although this is largely through calling others in a position to know, rather than through a text-based service (Aker, 2008; Jensen, 2007). In fact, it can be quite difficult to separate the effects of simply having access to a mobile from the effects of an agricultural service intervention (Aker, 2011). Moreover, there is widespread consensus that having a mobile affects many aspects of the lives of the rural poor, including a broadening of farmers' social networks, improving their ability to deal with emergencies, and making travel more efficient (Furuholt & Matotay, 2011; World Bank, 2012). Each of these enhancements can impact quality of life without necessarily affecting the prices of farm outputs.

There is evidence, however, that the availability of mobile phones has impacted prices of farm outputs in developing countries. In the widely cited Jensen (2007) study, following the introduction of mobile phones in Kerala, India, there were dramatic reductions in price dispersion across fish markets, and fisherman reported that waste was nearly eliminated as they could call ahead to find which market would value their catch the most. Overall, welfare was increased as gains exceeded both search and transportation costs. Aker (Aker, 2008, 2013) found similar reductions in price dispersion in grain markets in Niger, reporting reductions in grain price differences across markets following the introduction of cell phones ranging from 10 to 20%, with a larger impact for markets that are farther apart and those that are linked by poor-quality roads. Cell phones also have a larger impact over time: the more markets that get cell phone coverage, the greater the reduction in price differences. It is important to keep in mind that price dispersion reductions across markets can be a result of reduced search costs by traders who pick up crops at the farm gate and sell at various markets, rather than directly resulting in higher farm gate prices for smallholder farmers.

Further research by these authors finds that overall economic benefits appear to vary across types of crops, (e.g. perishables are impacted more than staples), and in addition to distance and road quality, were influenced by other contextual factors such as the competitiveness of the wholesale market sector in different regions (Aker and Fafchamps, 2011, 2013). Farmers in these studies did do more price searching but did not engage in price arbitrage and did not receive higher average prices than other farmers. Indeed, a re-examination of the impact of mobile phones on Kerala fisherman finds that the impacts in North Kerala were not replicated in South Kerala due to differing norms regarding the use of mobiles by market traders and differing market rules (Srinivasan & Burrell, 2013).

The evidence of impact on farmer welfare from the use of SMS-based market information services (MIS) is also mixed (Burrell & Oreglia, 2013). Fafchamps and Minton (2012) conducted an extensive analysis of the impacts of the Reuters Market Light (RML) service in India, comparing RML subscribers with similar farmers who don't subscribe to the system. RML is an SMS-based service that provides price and weather information to subscribers. Their controlled randomized experiment encompassed 100 villages in Maharashtra, India. They reported no significant differences between subscribers and non-subscribers in terms of prices received by farmers, extent of crop value addition, losses due to weather, differences in crop varieties planted, or cultivation practices. RML adoption rates were also lower than expected. On the other hand, a preliminary assessment of the Esoko market information service in Ghana found that farmers in the Esoko treatment group experienced a 7% increase in the prices they received for yams, which translated into a 6% gain (roughly $62-$69 USD) in annual household income (Center for Technology and Economic Development, 2013). The effect was even greater among those farmers in the treatment group who were actually making use of Esoko and understood the price information they were receiving. Surveys of these farmers suggest that the primary reason for the price increase was due to their ability to negotiate for higher prices with traders coming to the farm gate, not due to bringing the yams to markets where prices were higher. However, there were no price differences between treatment and control groups for more established crops such as maize and cassava, where information asymmetries may not have been so high, leaving less room for improvements in negotiations.

Burrell and Oreglia (2013) argue that market information services take information out of context and obtaining impersonal market price information may not be perceived as the most valuable way that farmers use their mobile phones. Adoption of MIS is lessened because there are other sources of information about price – often from calling trusted contacts. Moreover, knowing prices is different from having the ability to take advantage of this information. Transportation and possession of social connections in distant markets can also influence market access, among many other factors. A broad review of market information services described in a recent USAID Briefing further questions the sustainability of most systems, as it is unclear whether smallholder farmers can or will pay for the services given the uncertain benefit (USAID, 2013).

There are a number of other important gaps in our knowledge about the role of ICTs in agriculture in developing countries in addition to questions about the impact of market information services. As noted above, studies of MIS have observed relatively low rates of adoption, and others have found that adoption rates of ICT for agriculture interventions are especially low among the so-called "bottom of the pyramid", small-scale farmers and rural poor (Lokanathan and DeSilva, 2010). Rural farmers are acquiring mobile phones, but this does not necessarily mean that they will use value-added agricultural services. Some researchers focus on the issue of literacy, as many services rely on text messaging to deliver information. Because low literacy among smallholder farmers, and especially among women farmers, may be inhibiting take-up, some mobile services such as India's IKSL system provide information in voice form. Some argue for greater use of hybrid approaches that tie-in with traditional media such as radio that are more widely available and less dependent on literacy. Indeed, one study found higher farm gate prices for farmers who received market price information through an FM radio service (Svensson and Yanagizawa, 2009).

Beyond literacy problems, other issues to consider are costs, limited access to supporting infrastructure like electricity for charging phones, and complexity of phone operating systems that make use of text and data oriented services challenging for the rural poor. Given the rapidly changing infrastructure for mobile and Internet services in the developing world (including the rise of smartphones which passed feature phones in global sales for the first time this month according to a recent Gartner report)[17], there may be opportunities for rethinking service design to address literacy and complexity issues. Greater use of smartphones may make it easier to introduce new kinds of capabilities such as precision agriculture (Munyua, Aldera, & Jensen, 2008; Pehu et al., 2011) and crowdsourcing applications (Pehu et al., 2011; van Etten, 2011).

[17] http://www.gartner.com/newsroom/id/2573415

4.1 The role of gender in ICT for agriculture

Throughout the developing world, women are major producers of food with a recent FAO report estimating that women comprise nearly half of the population of people active in agriculture (FAO, 2011). In some contexts, women may outnumber male farmers due to the effects of HIV AIDS and men being more likely to migrate to cities for jobs (World Bank, 2009). Moreover, the FAO (2011) estimates that providing women equal access to resources for agricultural productivity can increase their output by 20-30 percent, which potentially could reduce global hunger by 12-17%.

However, just as women suffer from lower access to many assets such as land, credit, and information, researchers have found that women's access to and use of mobiles and other ICTs are constrained (Aker & Ksoll, 2012; Manfre & Nordehn, 2013; Porter, 2012). As shown earlier in Figure 15, women have less access to TV and radio, and according to ITU data, 16% fewer women have access to the Internet in developing countries than men.[18] Despite the global proliferation of mobile phones between 2000 and 2010, a 2010 GSMA and Cherie Blair Foundation study found that women were 21% less likely to subscribe to mobile phone service – a figure that increased to 23% in Africa and 37% in South Asia (GSMA and Cherie Blair Foundation, 2010). Cost was a major factor in the study determining likelihood of ownership, and among women in the "bottom of the pyramid" demographic category, only 26% owned a phone, although many who did not own a phone had some access through sharing and borrowing. Researchers who have looked at sharing practices, however, find that in some contexts it can constrain a woman's ability to use a borrowed or shared mobile for work (Burrell, 2010).

The stakes are important, as improving access to ICTs by women can help to address many of the resource and time constraints that have limited women's empowerment, especially in the agricultural sector (USAID, 2012d). Mobiles can reduce travel costs and time, enhance security for women, and promote greater independence, income, and access to professional opportunities (GSMA and Cherie Blair Foundation, 2010).

Mobile phone access appears to have benefited female farmers in a number of studies. Aker and Ksoll (2012), for example, found that access to mobiles in a farm household increased the diversity of crops planted, with a greater likelihood of women growing okra, a cash crop. Mobiles also were found to have benefited women-led dairy farms in Lesotho in a four-year study by Vincent and Cull (2013). Additionally, women seem to recognize the benefits of mobiles. A study in Uganda found that female farmers were more likely than men to use their mobiles to access agricultural information, despite lower overall use of mobiles among women (Masuki et al., 2010).

Research into women's use of mobiles in developing countries finds distinct differences in usage strategies. Women tend to have smaller and more local information networks

[18] http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2013.pdf

than men, rely more heavily on their spouses for information, and are more likely to use their phones to strengthen local relationships (Manfre & Nordehn, 2013). Manfre and Nordehn (2013) suggest a need to target more directly women with agricultural information services rather than relying on a "trickle down" effect that assumes information is always passed from husband to wife. There is a clearly a need for more research on what approaches can best improve women's access to and use of ICT-based systems that enhance agricultural productivity and market access.

4.2 Summary

The section has provided a selected overview of the scholarly literature assessing the impacts of ICT for agriculture services, observing that, while few dispute the potential benefits that ICTs can bring, the relatively few rigorous outcome assessments offer rather mixed findings. This research reveals the need for more careful assessment of impact, which can vary according to many social and contextual factors. There is clear evidence of variability in ICT adoption, use, and impact by age, gender, and income, among other factors, and such findings can have implications for the strategies used by the ICT4D community.

5. Results from a GCFSI field assessment on the use of mobiles and market information services among small-scale farmers

In order to supplement our background review and further understand the challenges and opportunities surrounding the application of ICT for agriculture, GCFSI researchers undertook a field assessment of mobile phone and market information service use among scale farmers in Kenya.[19] The assessment involved participant observations, group interviews, and in-depth interviews with individual farmers as well as individuals working on ICT and agricultural projects affiliated with NGOs like One Acre Fund (OAF), Animal Draft Power Program (ADPP) and Innovation for Poverty Action (IPA). Field work took place in rural villages in western Kenya in Bungoma, Mumias, Migori, and Homa Bay Counties – areas where agriculture is the primary activity. In addition to investigating mobile phone use by small-scale farmers, we further investigated awareness and use of MFarm, an acclaimed market information service. In total, 76 farmers (44 men; 32 women) participated in interviews over a ten-day period in June of 2013. Observations of participants attempting to use the MFarm application also informed our analysis.

Most of the farmers we interviewed owned a mobile phone, with 64 of the 76 participants reporting they had a handset. However, eleven of the 14 individuals who told us they did not own a handset were women, illustrating the well-documented access gap. We encountered only a few smartphones, and virtually no women had one of these types of devices. Farmers reported mostly using their phones for non-

[19] For more details, please see the accompanying GCFSI working paper, "Mobile Phone Illiteracy in Rural Kenya and its Implications for the Adoption of Market Information Services" 9/29/13 10:52 PM.

development purposes as communicating with family members, exchanging money and organizing meetings.

5.1 Key lessons from the assessment

Below, we briefly highlight several key findings from the assessment here, and direct readers to the Wyche and Steinfield (2013) working paper for a more detailed discussion of the field research.

- **Limited awareness of services**. Few of the farmers we interviewed were familiar with either MFarm or any other market information services. This suggests that commercial service providers need a more robust strategy to get the word out about their services and how they can be used.
- **Role of mobile phones for obtaining market information.** When asked how they learned about prices before going to the market, most respondents indicated that they called a trusted source – about a third called brokers who they typically referred to as their buyers. This highlights the dependence that smallholder farmers have on middlemen who can provide the necessary market access and transportation services. As found in other studies of Kenyan farmers (Crandall, 2012), there was a distinct preference for calling over texting, despite the costs for calls being higher than texts. After demonstrating MFarm and having farmers check the price of specific commodities at one of the five major markets in Kenya, we received varying responses regarding the utility of this information. Some felt that it would allow them to negotiate for higher prices, while others noted that they would not have much leverage since they had no way to actually bring their goods to another market.
- **Limited mobile phone competence**. The lack of familiarity with basic mobile phone functions was striking. Many respondents struggled to use their phone's text messaging features and did not know how to locate and read received texts, much less send texts. There was even a name for such people, who were called "red and green button" users by those with more expertise, due to their ability to only press the green button to make or receive a call and the red button to end one. This lack of basic mobile phone competence limits the utility of the many ICT for agriculture projects that hope to use mobiles to directly reach rural farmers.
- **Literacy and language problems**. A number of respondents had very limited or no reading and writing skills and, therefore, were unable to take advantage of texting. Even those who could read found the practice of inputting letters by pressing number keys multiple times to be confusing. This was further complicated by worn out keypads that no longer had letters visible, or where farmers had poor vision and no corrective lenses, so that in order to text they needed to remember which letters belonged with which numbers. Additionally, some were familiar with their local language, and perhaps Swahili, but not

English – yet MFarm and other text-based market information services tend to be primarily in English.

- **Lack of pre-paid credit**. Virtually all mobile phone subscribers in Kenya use a pre-paid mobile service. Most of the farmers we interviewed had little to no credit on their phones, limiting their ability to spontaneously use a fee-based market information service like MFarm, which charges 1 KSH to send a text requesting the price of a commodity.
- **Phone charging problems.** In many cases, respondents had phones with no battery charge and so were unable to use them during the demonstration, or their phones were not with them as they were elsewhere getting charged. This rendered the phone unavailable when it might be needed, further limiting its utility for many types of services that depend on real time information access.
- **Gender differences**. As noted above, a lower percentage of women than men had phones among our respondents. They further were less likely to report using their phone to call a broker to learn about prices, instead relying on their spouses or, as in the case of one widow who occasionally sold bananas at a local market for extra cash, learned about prices when she took her bananas to the market. They were more likely to have broken phones or phones without credit, suggesting that there remain important gaps in technology access that must be addressed if women are to be better served by ICT for agriculture services.
- **Role of community groups, farm collectives, and NGOs**. In a number of cases, the farmers we interviewed were part of farm collectives who worked with NGOs like OAF, ADPP, and IPA. Farmers in these groups were using their phones in richer ways, generally instigated by innovations from the NGOs. For example, OAF was testing out a mobile loan and repayment program with their farmers that allowed them to send out payments via M-PESA so that farmers could purchase needed farm inputs on time. Group leaders trained by OAF then collected weekly repayments from their local group that they then input into M-PESA and sent to OAF without incurring the risk of holding on to and transporting larger amounts of cash. OAF was also testing an alerting service that sent notifications to farmers for weather, planting, fertilizing, and harvesting updates, as well as a hot-line service for questions. IPA along with the Mumias Sugar Company worked with contract farmers and was testing the use of M-PESA to provide advance payments so that farmers would not have to wait the full 18 months until their sugar cane was harvested for income. Mumias sugar farmers also had ready access to company agents to call in questions. ADPP had someone from MFarm come in and teach their sweet potato farm collective about the service, and these were the only farmers in our interviews who had used the service. More often, people in the collective would simply contact their group leader, who would relay the market price information they obtained from MFarm to the group. All of these examples illustrate how important NGOs and farmer collectives are in bringing innovative practices to

smallholder farmers and providing the complementary resources needed to take advantage of ICT-based services.

Our field assessment offers some critical context that provides some balance to the discussion about the role of ICTs in agriculture in developing countries. In the excitement that followed the rapid uptake of mobile devices, there was a rush to introduce many new services. Our assessment challenges a number of underlying assumptions – that owning a mobile phone means it is available to be used, and the owner knows how to use the various features embedded in his or her phone. These are not necessarily realistic assumptions. The assessment further underscores the need to better educate farmers regarding basic mobile phone operation if they are to take advantage of available services. It may be, for example, that one of the reasons M-PESA has been able to achieve critical mass in Kenya is due, not only to the widespread availability of kiosks, but also because agents can directly instruct users as they attempt to set up accounts, add funds, and receive funds with the service. This kind of direct and often repeated instruction has not been used in typical market information services. Additionally, our report highlights the gender inequalities that must be overcome if women are to be reached and served by ICT for agriculture interventions. Finding ways to address the lack of basic complementary infrastructure – such as charging facilities – as well as to improve the design of services such as through the use of local languages are also critical. Finally, strategic partnerships with intermediary organizations that can help farmers make productive use of their mobile devices can improve the prospects for ICT for agriculture interventions.

6. Problem Definitions

Based on our review and field assessment, there remains much to be learned about how we can best leverage ICTs to enhance agricultural production and farmer welfare, especially among smallholder farmers upon whom much of the developing world depends. In particular, research is needed to better understand the factors that influence smallholder farmers' adoption of ICT-based services, what impact these services have, and whether services have different implications for men vs. women farmers. Note that these research issues have implications for all of the other areas of focus of the GCFSI. For example, an ICT-based service can focus on improving farmer productivity in areas impacted by climate change (MT1), provide support for post-harvest value-added activity by smallholder farmers (MT2), or enhance training and access to extension (MT3). We offer the following set of action items for research that have emerged from our review.

a. There is a need to better understand adoption patterns for value added agricultural ICT services. Many services aimed at "bottom of the pyramid" farmers are introduced with great fanfare but, as we have seen, are not taken up by the farmers they are designed to support. Researchers investigating an ICT for agricultural service need to provide a rigorous but focused assessment of the factors that contribute to adoption and successful use of a particular value-added ICT service by target actors in the food system value chain. The research must identify both barriers and facilitators to adoption of ICT-based value added agricultural service, including a realistic assessment of whether the service as designed can be sustained through fees or other funding sources in order to inform the private sector, NGOs, and other policy makers. Findings from the research can help guide the design of services to make them more usable and accessible.

b. There is a need for a better assessment of the impacts of using value-added agricultural ICT services on smallholder farmers and other actors in the food system value chain. Outcome measures must go beyond demonstration of usage and include both intermediate outcomes, such as on farm productivity, and broader outcomes of interest to the development community such as impacts on farmer income and quality of life. Researchers must provide a focused and rigorous assessment of the impacts of particular value-added agricultural ICT services and need to identify the mechanisms that explain who benefits, in what ways, why some benefit while others do not, and what implementation approaches improve likelihood of benefits.

c. There is a need to carefully investigate how new ICTs can support women actors in the food system value chain, given the evidence that the use of mobiles by female farmers can enhance outcomes, but their access to and use of mobiles and other ICT services are very constrained. Moreover, the current design of services may discourage female farmers from successfully adopting and using services. Researchers need to provide an assessment of both the challenges for women as well as the strategies to empower women through ICT-based value added services that incorporate gender-sensitive features. This research must identify specific constraints faced by female farmers – as well as women working in other segments of the food system – and test alternative strategies for designing and deploying ICT-based services that empower women.

7. Conclusions

This white paper has provided a broad review that highlights both the opportunities and the challenges involved in applying information and communication technologies to enhance food systems in developing countries. The explosion in access to mobile devices and the Internet throughout the developing world has led to many exciting innovations aimed at improving the productivity of small-scale farmers. Applications use both traditional media such as radio and television and newer media such as mobile phones and the Web. Our review highlights the potential effectiveness of emerging "edu-tainment" programs to help educate farmers, especially when using a participatory and localized approach that is integrated with newer interactive, mobile and social media. The use of mobiles to reach directly to small-scale farmers, expanding the reach of traditional agricultural extension and providing market information is increasing. Farmers are also making use of mobile payment services as they become more integrated into everyday economic activities.

Yet, despite these exciting opportunities, this white paper also documents research that questions the effectiveness and sustainability of many existing interventions. Large scale assessments fail to find that farmers who use market information services are getting better prices. Perhaps such systems benefit brokers and traders as much as they do farmers, or it may be that information on prices is obtained in other ways, and non-subscribers are not at that great a disadvantage. Or, it may be that services just are not being used enough, due to many of the factors highlighted in our field assessment. At a minimum, our assessment has found that we cannot assume that just because farmers own mobile phones that they understand how to use them, that they can afford to use them, that phones are charged or otherwise in working order, that the service design itself is usable, and that the use of the service conforms with established local norms. Rather, more attention to educating farmers about how to use ICTs is needed in addition to the focus on agricultural and business practices.

Our review has also emphasized how the use of ICTs is mediated by gender, not just due to the lower levels of access experienced by female farmers in developing regions, but also due to the differing usage strategies and patterns of men and women. Efforts, therefore, cannot end with programs aimed solely at enhancing access to ICTs. Rather, service design must take into account these diverse use practices and special efforts to provide services tailored to the needs of women are needed.

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