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Mobile Technology Trends and their Potential for Agricultural Development

Heike Baumüller

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Abstract

Mobile phones have spread around the developing world at an amazing speed. Their proliferation has given rise to numerous mobile phone-enabled services (m-services) in the areas of health, education, agriculture and entertainment. However, to date many of these services are barely scratching the surface of what is technologically possible. This paper examines the potential of recent mobile technology trend to enhance the functions and reach of m-services, with a focus on promoting agricultural development among smallholder farmers. To this end, the paper identifies three broad trends: the growing diversity of devices to access mobile content and functions, the Internet of Things that links sensors and 'smart objects', and the power of social networks and a large user base to gather data, collectively develop solutions and facilitate learning. For each of these trends, the paper reviews the current state of the technologies and highlights actual and potential applications in the agriculture sector. The extent to which benefits can be realised on a large scale will depend on a number of factors. Thus, the paper outlines two possible scenarios how the trends could evolve in the future under different assumption and assesses the implications of these scenarios for the provision of m-services that suit the needs and capacities of farmers in developing countries.

Keywords: agriculture, mobile phones, mobile connected devices, m-services, internet of things, cloud computing, big data, crowdsourcing, social networks

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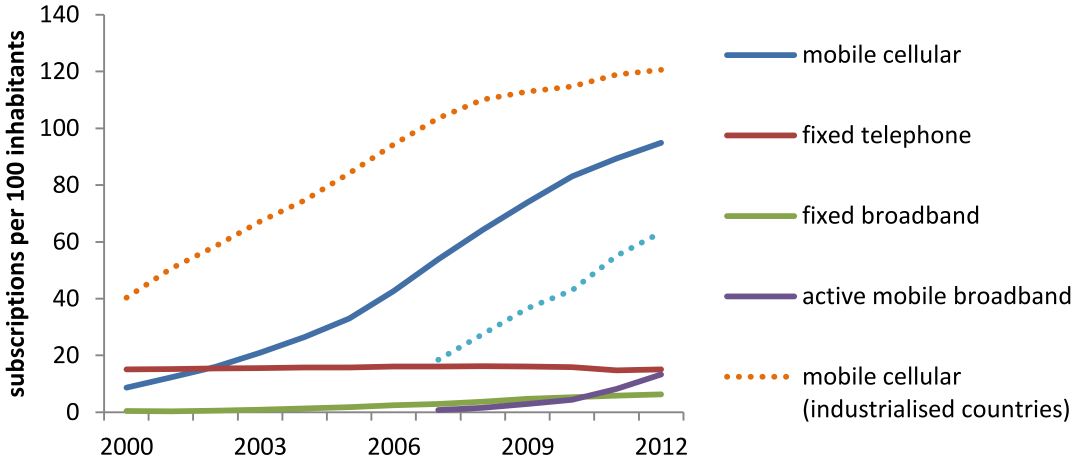
1 Introduction

Mobile phones have spread around the developing world at an amazing speed. In Kenya, for instance, mobile phones and the mobile payment service M-Pesa were adopted faster than any other popular technology in the USA, such as the radio, the telephone, the computer, the colour TV or the automobile (Suri, Jack, & Stoker, 2012). While developing countries still lag behind industrialised countries in terms of subscription rates, the gap has slowly been closing since 2008 (Figure 1). The growth in mobile phone subscription rates in the developing world has dwarfed that of fixed telephones, with an annual growth rate of 22% between 2000 and 2012 compared to 0.02% annual growth in fixed lines. In recent years, mobile broadband rates have also outpaced fixed broadband, growing at an impressive rate of 76% annually between 2007 and 2012.

Figure 1: Telephone and broadband subscription rates (2000-2012)



Note: Unless otherwise stated, the figure shows subscription rates for developing countries. Data for mobile broadband subscriptions are not available prior to 2007. Mobile broadband data for 2012 is an ITU estimate.
Data source: ITU website (accessed 29 July 2013)

The proliferation of mobile phones has given rise to numerous mobile phone-enabled services (m-services) in the areas of health, education, agriculture and entertainment, especially since 2009. A review of m-products and services found over 800 live initiatives in the developing world (as of September 2012) (Hatt, Wills, & Harris, 2013). Mobile phones and m-services could present particular opportunities for farmers in developing countries who in the absence of landlines and computers often lack alternative means of telecommunication and internet access (see Baumüller, 2012 for an overview of m-services for farmers). Poor and marginalized farmers in particular may be able to use their mobile phones to access services that are otherwise inaccessible due to barriers of space and social standing (von Braun & Torero, 2006). While agriculture-related m-services still account for only a small share of m-services (Hatt et al., 2013), the large untapped rural market offers potentially significant business prospects for service providers.

To date, many of the agriculture-related m-services are barely scratching the surface of what is technologically possible. With smartphone penetration and 3G networks still limited in many rural areas, most mobile applications for agriculture in developing countries are designed for low-tech mobile phones and delivery technologies such as SMS or voice services (Hatt et al., 2013; Qiang, Kuek, Dymond, & Esselaar, 2011). Technologies being applied in precision agriculture, which employs ICT tools to monitor intra-field variations and manage crop production accordingly, offer a glimpse of the potential of modern ICTs to boost agricultural productivity. To date adoption rates of these technologies have not lived up to expectations, however, even in countries with more advanced agricultural sectors, let alone among small-scale farmers (McBratney et al., 2005).

Recent technological advances could help to increase the use of modern mobile technology tools in agriculture. Technologies, such as smartphones, tablets and sensors, are becoming cheaper and thus more affordable for lower income users in the developing world. Mobile networks are also improving. In Africa, for instance, close to US$ 4 billion have been invested in new submarine cables, almost doubling the data capacities in just two years (Schumann & Kende, 2013). By 2012, 40% of the population in Sub-Saharan Africa lived within 25 km of an operational fibre node following a roll-out of terrestrial fibre optic cables across the continent (Hamilton Research, 2012). While rural areas still lag behind urban areas in terms of network coverage and speed, the gap is slowly closing.

Improving access to hardware and infrastructure could lay the foundation for exploiting new mobile technology trends in agriculture. This paper identifies three such broad trends, i.e. the growing diversity of devices to access mobile content and functions, the Internet of Things that links sensors and 'smart objects', and the power of social networks and a large user base to gather data, collectively develop solutions and facilitate learning. All three trends mark a shift in the way that individuals and companies use the Internet from single devices providing certain services to ecosystems of diverse interconnected devices that offer multiple applications or services (Taylor, 2012). The paper reviews the current state of these technologies and highlights actual and potential applications in the agriculture sector. The extent to which benefits can be realised on a large scale will depend on a number of factors. The paper identifies some of the key factors and outlines two possible scenarios under different assumptions.

The paper focuses on mobile connected devices which are understood to include all connected devices (as defined by the GSM Association[1]) that use wireless networks, e.g. mobile PCs, tablets, routers, mobile phones and certain machine-to-machine communication (M2M) devices. For the purpose of this paper, mobile connected devices are divided into two categories, namely personal mobile devices (i.e. devices that allow users to access m-services) and M2M devices, which are defined as devices "that are actively communicating using wired and wireless networks, that are not computers in the traditional sense and are using the Internet in some form or another" (OECD, 2012, p. 7).

2 Mobile Technology Trends

2.1 Diversity of personal mobile devices and delivery channels

2.1.1 Personal mobile devices

Devices to access mobile services have diversified in recent years (see Box 1 for an overview of personal mobile devices and delivery technologies). Basic and feature phones are slowly being displaced by smartphones in many industrialised countries while tablets complement PCs and laptops. Smartphone use has grown faster than expected. While Ericsson in 2012 predicted the total number of smartphones to reach 3.3 billion by 2018 (Ericsson, 2012), the estimate was revised to 4.5 billion just one year later (Ericsson, 2013). Smartphones accounted for around 19% of global mobile phone subscriptions in 2012 and are predicted to make up 50% of subscriptions by 2018 (Ericsson, 2013). In the US and Europe, this share has already been reached (Hatt et al., 2013). While smartphone sales are predicted to stagnate in industrialised countries in the coming years, future growth is expected to be driven by large emerging markets, notably Brazil, Russia, India, China and Indonesia (Canalys, 2013).

[1] The term 'connected devices' is used by the GSM Association in the context of its Connected Life initiative to describe "all devices used for transmitting and receiving packet data telecommunications via any wide-area or local area network", including PCs/laptops, mobile handsets, tablets and numerous M2M applications (GSMA, 2012, p. 3).

For now, basic and feature phones are still dominating in developing countries where less than 10% of the people are thought to have a smartphone (Hatt et al., 2013). Smartphone penetration rates are particularly low in Africa and South Asia. This trend is also reflected in the availability of m-services on different devices. A survey of m-services provided in developing countries across sectors found that 85% of services are targeted at basic or feature phones (Hatt et al., 2013).[2] Just 33% are developed for smartphones (mainly in mLearning and mEntrepreneurship), slightly more than for PCs (31%) (Hatt et al., 2013). SMS was the most common delivery technology (67% of services) followed by USSD (40%), while the web and apps accounted for just 34% and 24% respectively. Voice-based services were also low at 25% (including interactive voice response systems) due to their complexity and cost.

Box 1: Personal mobile devices and delivery technologies

Devices

Basic phone: Offers basic voice services (telephony/voice mail), SMS and USSD based services.

Feature phone : Basic phone features plus: Internet enabled, supports transmission of picture messages, downloading music, built-in camera

Smartphone: Feature phone features plus: Graphical interface and touchscreen capability, built-in Wi-Fi and GPS (global positioning system)

Tablet: Smart phone features plus: Larger screen, increased computing power, front and rear facing cameras, additional ports (e.g. USB)

Mobile PC: Includes laptop or desktop PC devices with built-in cellular modem or external USB dongle.

Mobile router: A device with a cellular network connection to the internet, and Wi-Fi or Ethernet connection to one or several clients (such as PCs and tablets).

Delivery technologies

Voice: Basic telephony services, with voice delivered over a mobile network

IVR: Interactive voice response, allows a computer to interact with humans through & voice recognition navigation and DTMF tones via keypad

SMS: Short Messaging Service, allows exchange of short text messages between mobile phone devices

USSD: Unstructured Supplementary Service Data. A synchronous message service creating a real-time M2P connection allowing a two-way exchange of data, mostly through menu structures

Text-to-Speech: Computer or handset based service that generates speech using text input

Web: A system of interlinked hypertext documents accessed via the Internet; also accessible via enabled mobile devices

Apps: a software application designed to run on mobile devices. (typically smartphones, and tablet computers)

WAP: Wireless Application Protocol for accessing information over mobile network. WAP browsers typically found on older feature phones.

Sources: Definitions compiled from Hatt, Wills, and Harris (2013, p42) and Ericsson (2013, p6).

High demand for mobile Internet and price declines are expected to drive smartphone adoption in developing countries. As a possible sign of this trend, Kenya's Safaricom has decided to stop selling feature phones in its retail outlets. At the same time, the market is seeing a convergence of high-end feature phones and low-end smartphones in terms of price and functionalities (Hatt et al., 2013). In Kenya, for instance, the Chinese company Huawei is selling their Ideos smartphone for around US$80-100 while the Nigerian company Tecno is set to sell its N3 smartphone for US$92 (Southwood, 2013). In comparison, a feature phone will retail for around US$40-50. Thus, to be competitive, a

[2] The survey included mobile services provided through basic phones, feature phones, smartphones, PCs/laptops, tablets and other devices (e.g. personal digital assistants).

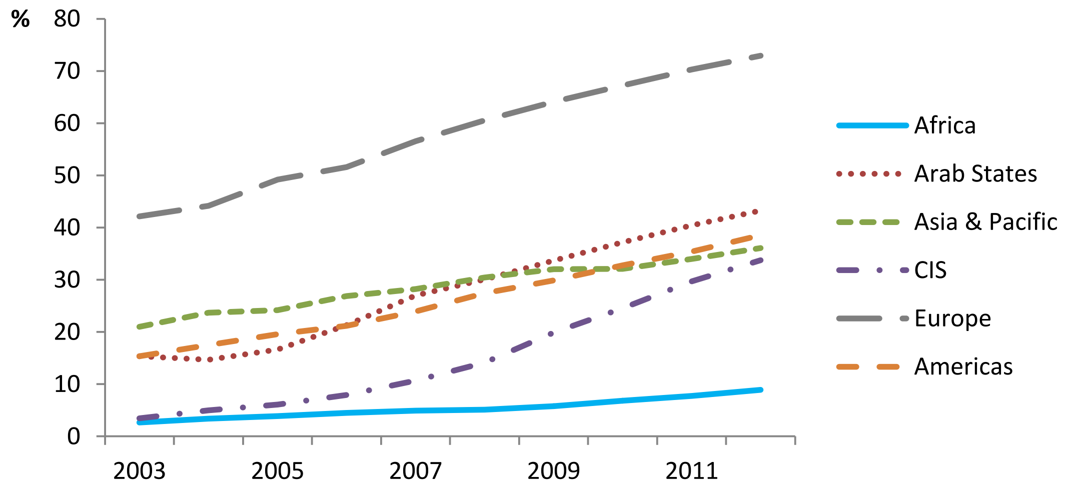
low-end smartphone would need to cost around US$60-70 (ibid). As smartphones become cheaper, they are likely to compromise on quality of build and battery power which could be particularly problematic for rural areas (Hatt et al., 2013).

Some observers warn against overestimating smartphone expansion, however. While global smartphone shipments for the first time overtook feature phone shipments in early 2013 (Costello, 2013), lower-tech phones still make up the large majority of existing devices (mobiThinking, 2013). As Jon Hoehler, manager of mobile technologies at Deloitte Digital South Africa, notes: "The key is to look at the installed base of devices - actually devices in hand - rather than the sale of new devices. In many emerging markets, handsets are reused, resold or passed down through the family." (Costello, 2013). Ericsson (2013) predicts that subscriptions for lower-tech phones will remain high, declining only relatively little to 4 billion by 2018 compared to 5 billion in 2012. Thus, the prevalence of basic and feature phones is expected to continue in many developing countries in the short and medium term, in particular among lower-income groups (Hatt et al., 2013).

Mobile PCs, including laptops or desktop PCs, can also be used to access the mobile network. This functionality is becoming easier and more cost-effective, for instance through cheap external USB dongles, built-in WiFi or by using the mobile phone as a mobile hotspot. In particular laptops are often equipped with built-in wireless connections. Computer ownership in developing countries continues to be low, growing at just 6.3% per year between 2003 and 2012. By 2012, just 28% of households were equipped with a PC or laptop compared to 73% in industrialised countries.[3] Africa, where computer ownership rates have only started to pick up slowly since 2008, lags furthest behind with just 9% of households owning computers (Figure 2). In terms of individual ownership, a similar share of people owned a computer as a smartphone in 2012 (5% compared to 8%) and almost as many m-services were available on both device types (Hatt et al., 2013).

However, while ownership rates for smartphones and computers may be comparable, smartphones with mobile subscriptions far outnumber mobile computers globally. Ericsson (2013) estimates global mobile subscriptions for PCs, tablets and mobile routers at just 300 million compared to 1.2 billion smartphones in 2012. While the number of mobile computers is projected to increase to 850 million and thereby overtake fixed broadband subscriptions by 2018, they will still be dwarfed by the 4.5 billion projected smartphones.

Figure 2: Share of households with a computer (by region)



Data Source: ITU ICT-Eye (accessed 28 July 2013)

[3] ITU ICT-Eye, www.itu.int/icteye, accessed 28 July 2013

Tablet use in most developing countries is still low and just 9% of m-services reviewed by Hatt, Wills, and Harris (2013) were developed for tablets. However, global tablet shipments have been growing rapidly and are expected to exceed portable PCs in 2013 and the entire PC market in 2015 (IDC, 2013a). Their adoption in developing countries could be boosted by the production of lower-cost tablets in emerging economies. In India, for instance, the tablet market grew by 901% within a year to reach 2.66 million units in 2012 (IDC, 2013b). Three Indian companies are among the top 5 tablet producers and together account for 26% of tablet sales in India. Because tablets use batteries and mobile data connections, they tend to be less vulnerable to power cuts and have lower electricity costs compared to PCs (Sylla, 2013). This may also make the attractive for Internet cafés, as seen for instance in Senegal where the first Tablet Café opened in 2013 with funding from Google.

2.1.2 Cloud- and web-based technologies

The emergence of cloud computing is changing the way that m-services are used on personal mobile devices. Cisco defines the mobile cloud broadly as "mobile services and apps delivered from a centralized (and perhaps virtualized) data center to a mobile device such as a smartphone" (Taylor, Young, Kumar, & Macaulay, 2011, p. 2). The underlying idea of cloud computing is to offer computing, storage and software 'as a service' rather than running them on local IT infrastructure (Voorsluys, Broberg, & Buyya, 2011). The analyst firm Gartner predicts that by 2016, 40% of mobile apps will make use of cloud-based services (Ferguson, 2013). The National Institute of Standards and Technology distinguishes between three types of cloud services (Mell & Grance, 2011; Voorsluys et al., 2011):

- software as a service (i.e. using an application running on cloud infrastructure),
- platform as a service (i.e. a development and deployment environment that allow users to create and run their applications) and
- infrastructure as a service (i.e. the provision of virtualized computing resources such as processing, storage, networks and communication)

Cloud computing is also making it easier for services to be accessed via the web, a trend that Korkmaz, Lee, and Park (2011) refer to as 'web-centricity'. The authos predict that by using the new Internet standard HTML5, programs will increasingly run through the web browser rather than a specific operating system. They estimate that more than 50% of all mobile applications will switch to HTML5 within three to five years. Another approach to accessing services via the web was developed by the Australian company biNu which promises to offer 'Your smartphone in the cloud' on feature phones by running apps and services through the web browser.[4] This service is claimed to be fast and more cost-effective because the data is heavily compressed.

Cloud and web-based technologies are supporting the convergence of feature and smartphones by putting smartphone-like features into java-enabled feature phones (Afrinnovator, 2011). The phone then functions as an interface to access services which are run somewhere else, thus requiring less processing power than when running the service on the device. As a result, the distinction between different device types may no longer be as important, as high-end feature phones catch up to smartphones in terms of functionality while retaining advantages such as robustness, ease-of-use and longer battery life (Box 2). Tablets will also benefit from cloud- and web-based technologies which will enable them to bridge the gap between smartphones and PCs/laptops. In addition, these technologies enable users to shift from using one device to access multiple services to using multiple devices to access individual services.

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[4] www.binu.com

Box 2: Battery life

The choice of phone and its usage will have implications for the life of the battery. Basic and feature phones tend to have a longer battery life because of their limited features (such as smaller and often black & white screens) and low processing power. Battery lives vary between phones, but in general lower-tech phones will only need to be recharged ever few days. As feature phones become more complex, their battery life also tends to shorten. Smartphones require more energy due to the size and quality of the screen, data transfer through wireless connections (such as 3G, WiFi, Bluetooth or GPS) and processing requirements for apps. Most smartphone batteries tend to last for only 1-2 days. Thus, as m-service and the required phones to use them become more sophisticated, battery life could become a constraint in areas with costly or unreliable access to electricity.

One way to overcome limited battery lives is to add battery power externally, e.g. through a second exchangeable battery (although some devices, in particular many smartphones and tablets, come with a built-in battery), or portable USB packs and cases which incorporate batteries to recharge smartphones. Users may also keep several phones for different uses (e.g. low-end phones for basic uses and higher-tech phones for more sophisticated applications) although the need to switch SIM cards between phones makes this a cumbersome option. Other opportunities to extend battery lives are to improve the efficiency of the battery itself, the power-efficiency of the hardware (in particular the chip) or the processing power needed to run software (Wagner, 2013).

Other manufacturers are responding to these constraints by developing phones particularly suited for emerging markets, such as the Nokia Asha 501 launched in May 2013 (Bean, 2013). Nokia claims that the phone's battery lasts for 17 hours of talk time and 48 days of standby time. The phone blurs the line between feature phones and smartphones. Thus, while the phone can only use the 2G network, it nevertheless offers some of the same features as smartphones through its touchscreen and apps. The embedded Nokia Xpress Browser compresses Internet data by up to 90%, according to Nokia, thus reducing data usage and costs. The phone is priced at around US$ 100.

2.1.3 Mobile broadband

Cloud- and web-based services require fast and reliable Internet access. The McKinsey Global Institute has identified mobile Internet and cloud computing as two of the 12 most disruptive technologies by 2025 by facilitating ubiquitous connectivity, service delivery and productivity increases (Manyika et al., 2013). Reflecting demand growth for Internet access in general, global mobile broadband subscriptions have been expanding rapidly to reach 2.1 billion in 2013, with an annual growth rate of 40% since 2007, thus making it the most dynamic ICT sector (ITU, 2013) (see Box 3 for a definition of mobile broadband). Subscriptions are predicted to expand to 7 billion by 2018 (Ericsson, 2013).

Mobile broadband subscription rates in developing countries have grown from 0.8% in 2007 to 20% in 2013 with an annual growth rate of 71%, overtaking fixed broadband in 2011 which have largely stagnated.[5] By 2013, mobile broadband rates were more than three times higher than fixed broadband rates and mobile broadband is often the only access to broadband connections in many developing countries. However, the developing world continues to lag far behind industrialised countries where three quarters of the population subscribed to active mobile broadband in 2013. Since 2007, when data on mobile broadband subscription rates first became available, the gap has been continuously widening (Figure 1). With just 11%, Africa trails furthest behind.

[5] ITU statistics, www.itu.int/en/ITU-D/Statistics, accessed 1 August 2013. Data for 2012 and 2013 are ITU estimates.

Box 3: Mobile broadband

While the term 'broadband' is generally associated with high-speed internet access, there is no commonly agreed definition. The associated speed has evolved over time as technological capacities (e.g. cellular network speeds) and data requirements for services (e.g. more complex web sites or streaming of music or videos) have increased. Thus, the ITU (2003) notes: "The term "broadband" is like a moving target. Internet access speeds are increasing all the time. As technology improves, even ITU's recommended speeds will soon be considered too slow". Similarly, the US Federal Communications Commission states that "broadband speed threshold benchmarks are not static and . . . 'as technologies evolve, the concept of broadband will evolve with it'" (FCC 2010, para15, citing the 1999 First Broadband Deployment Report, para25).

For the purpose of this paper, mobile broadband is understood to include 3G networks or faster. Others follow a similar definition. The ITU, for instance, compiles its statistics of mobile broadband subscriptions based on broadband downstream speeds of at least 256 kbit/s, such as WCDMA, HSDPA, CDMA2000 1xEV-DO or CDMA 2000 1xEV-DV (i.e. services typically referred to as 3G or 3.5G) (ITU, 2011a). Ericsson uses a similar definition in its Mobility Report (Ericsson, 2013). Others set the limit higher. The FCC in its 2010 Sixth Broadband Progress Report revised its specification of broadband speeds from 200 kbps in both directions to actual download speeds of at least 4 Mbps and actual upload speeds of at least 1 Mbps (FCC, 2010). The Kenya National Broadband Strategy defines broadband as "Broadband connectivity that is always-on and that delivers a minimum of 5mbps to homes and businesses for high speed access to voice, data, video and applications for development." (MIC 2013, p6).

Network speeds also vary considerably between and within countries. While 2G networks are already widespread, covering at least 90% of the world's population, only around 45% benefitted from 3G signal in 2011 globally (ITU, 2011b). LTE (also referred to as 3.9G) networks are only slowly being introduced in developing countries while 4G networks are still at an early stage of development (Ericsson, 2013). Large gaps in reliable broadband coverage remain in particular in many rural areas of the developing world due to the high cost of network roll-out, low returns on investment for MNOs and lack of access to the electricity grid to power the network sites (Hatt et al., 2013). Data rates can also vary within different networks (e.g. 2G or 3G) since there is no binding standard to ensure certain speeds. In Ghana, for instance, data rates for almost all (fixed) broadband users range between 256 kbit/s and 2 Mbps while close to 60% of users in Morocco enjoy data rates of 2-10 Mbps (ITU, 2011b). Moreover, advertised speeds do not necessarily reflect real speeds which may be lower (ibid).

The cost of broadband access also differs. The ITU estimates that by early 2013, the cost of an entry-level mobile-broadband plan amount to 1.2-2.2% of monthly per capita GNI in developed countries and 11.3- 24.7% in developing countries (depending on the service provided) (ITU, 2013). Prices are particularly high in Africa where a computer-based plan with 1GB of data volume represents more than 50% of per capita GNI (ibid) Within Africa, prices can vary widely, ranging from less than 20 US$ per GB in Tanzania, Kenya and the Gambia (for low usage of up to 100 MB) to over 100 US$/GB in Botswana, Mozambique, Zambia and South Africa (Schumann & Kende, 2013).

Different options are being explored to close the coverage gaps, improve network speeds and reduce costs, but many are still at an early stage. Wireless local area networks (WLAN) using radio waves, such as WiFi, appear particularly promising. Such networks could be used to provide the last mile infrastructure between the cellular network and users by allowing devices to establish a broadband connection through wireless network access points (with a range of about 30-100 m). The EU estimates that 71 per cent of all EU wireless data traffic in 2012 was delivered to smartphones and tablets using WiFi and the share is expected to increase in coming years (Marcus & Burns, 2013). WiMAX (Worldwide Interoperability for Microwave Access) is another wireless data transfer standard, but with a wider bandwidth and range than WiFi (up to 30 km for fixed stations and 5-15 km for mobile stations). Broadband connections can also be provided through satellites, though usually at a higher cost and lower quality (Schumann & Kende, 2013). Other examples of innovative solutions being tested include:

- the use of TV white space (i.e. unused bands of spectrum between channels) being trialled by Google in South Africa and Microsoft in Kenya (PCWorld, 2013),
- Google's solar-powered balloons floating in the stratosphere,[6]
- The BRCK developed by the Kenyan company Ushahidi, a portable hub which supports up to 20 devices through WiFi, provides continuous internet connection by switching between Ethernet, WiFi and 3G/4G mobile phone networks as available and can run for 8 hours on battery in case of a power outage,[7]
- The use of smartphones to set up a mesh network using the phones WiFi connections being trialled by the Flinders University in Adelaide, Australia.[8]
- The German Fraunhofer Institute for Open Communication Systems (Fraunhofer FOKUS) is trialling a wireless backhaul technology (WiBack) in several African countries which aims at providing cost-effective, high quality broadband connections in rural areas by linking users with existing networks (e.g. GSM, satellite or fibre optic cables).[9]

These options could complement traditional licensed spectrum networks such as 2G or 3G to create so-called heterogeneous networks (HetNets) with multiple types of access nodes in a wireless network.

To circumvent the lack of broadband connections, some developers are also finding other ways to increase the functionality of low-tech phones without requiring Internet access. ForgetMeNot Africa, for instance, uses eTXT which allows users to update their Facebook accounts, send and receive email and chat over the Internet on any mobile phone via SMS.[10] In Kenya, for instance, Safaricom and Yu have launched services using the ForgetMeNot Africa technology where mobile phone subscribers can email a contact by sending an SMS to a number assigned to that individual's email address. Similar services are also available in other African countries, such as Nigeria, Lesotho, the Republic of Congo, Cap Verde and Zimbabwe.

2.1.4 M-services offered through diverse devices to farmers

Delivery technologies commonly used to offer m-services to farmers include SMS (e.g. searchable database or regular updates) as well as IVRs, voice recordings, helplines or the web (Baumüller, 2012). Only a few services make use of smartphones, such as *Sauti ya wakulima* in Tanzania to record audio and images to share with farmers or the SAP supply chain management system for cashew and shea butter in Ghana. An example of a tablet (and smartphone)-based agricultural m-service can be found in Tanzania where the social enterprise Sustainable Harvest has deployed the *Relationship Information Tracking System (RITS)* which provides coffee farmers cooperatives with supply chain management tools to track production quantities, production and processing methods and delivery (Hall, 2011; Sustainable Harvest, 2012). *RITS* has been developed for the iPad and iPhone, but can also be used through any web browser.

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[6] www.google.com/loon
[7] brck.com
[8] www.servalproject.org
[9] net4dc.fokus.fraunhofer.de/en/projects/wiback.html
[10] en.wikipedia.org/wiki/ForgetMeNot_Africa

Many more and increasingly sophisticated m-services can be envisaged that take advantage of the technological capacities of different mobile devices, the enhanced computing powers of devices that use cloud- and web-based services, and the ability to access a service from multiple devices. For instance, smartphones or tablets can convey larger amounts of information than can be sent through an SMS, e.g. on different farming techniques, input suppliers, potential buyers or market prices. Cloud- and web-based services allow users to run more complex applications, e.g. to analyse price trends or access detailed weather forecasts. Web-based banking services could also enable farmers to make m-payments and access their account through multiple mobile devices. As will be discussed in more detail in Section 3, these opportunities will need to be weighed against potential constraints and trade-offs such as network capacities, costs, battery power or usability.

2.2 Internet of Things

2.2.1 IoT technologies

A technology trend that is predicted to revolutionize the way people live and work is the Internet of Things (IoT). In the IoT, "sensors and actuators embedded in physical objects … are linked through wired and wireless networks, often using the same Internet Protocol (IP) that connects the Internet" (Chui, Löffler, & Roberts, 2010, p. 1). The phrase was coined in the late 1990s by Kevin Ashton, co-founder of the Auto-ID Center at the Massachusetts Institute of Technology (Ashton, 2009). Mark Rolston, chief creative officer at the San Francisco–based design firm Frog Design, predicts: "The mobile computers killing the PC will themselves be replaced as computing becomes embedded into the world around us." (Rolston, 2013)

The underlying idea is not necessarily new. As the OECD (2012, p. 8) notes: "From the earliest days, in the use of information technologies, computers have processed signals from external sources". What has changed is the sheer scale, enabled through the declining cost and size of the required technologies, the use of the Internet Protocol, ubiquitous networks and significant increases in storage and computing powers (including cloud computing) (Chui et al., 2010; OECD, 2012). As a result, communication modules can now be installed in nearly any device, thus allowing the Internet to expand into previously unreachable places (Evans, 2011).

Chui et al. (2010) identify two broad areas of application. The IoT can be used to *gather and analyse information*, for instance to track the movement of products through the supply chain, report on environmental conditions (such as soil moisture, ocean currents or weather) or monitor a patient's health. The IoT can also help with *automation and control* by converting the collected information into actions through a network of actuators, e.g. to optimise processes or resource consumption, or to manage complex autonomous systems.

The GSMA predicts that the number of connected devices will increase from 9 billion in 2012 to 24 billion devices in 2020 (GSMA & Machina Research, 2012). Cisco estimates the number of internet-connected devices to reach 50 billion by 2020 (Evans, 2011). While mobile handset make up the majority of these devices today, machine-to-machine communication (M2M) devices, such as radio-frequency identification (RFID) tags, sensors or meters, are expected to become increasingly widespread. The GSMA and Machina Research estimate that M2M devices will grow from 2 billion in 2012 to 12 billion in 2020. M2M devices will constitute the main building blocks of the IoT by collecting data which is then transmitted through networks to an M2M management platform which analyses the data for the user (OECD, 2012). The OECD (2012) believes that Wireless Personal Area Network technologies are likely to be used for indoor or short range M2M applications while cellular networks (2G, 3G, 4G) will be used for applications requiring dispersion and mobility.

Most M2M applications require a power source to perform their tasks and communicate with the wireless network, such as a battery or access to electricity (e.g. the grid or generators). Given that the number of M2M devices is expected to increase by the billions, regularly changing or manually recharging batteries will not be feasible, in particular where they are integrated into moving or remotely located objects. Even if the devices are stationary and easy to reach, the lack of constant electricity in many parts of the developing world could limit their widespread deployment. Researchers are looking into ways for the devices to generate their own electricity from environmental elements such as vibrations, light, and airflow (Evans, 2011). The BRCK described above could also provide a power source for multiple sensors (as well as a means to transmit the collected data), by linking the sensors to external power sources, such as the electricity grid or a solar panel, and providing back-up power through the built-in battery.

2.2.2 M-services offered through the IoT to farmers

In agriculture, the IoT and M2M devices have found application in precision agriculture (even if the terminology of the IoT is not necessarily used, especially in the early days of precision agriculture). Through the use of ICTs such as global positioning and information systems, remote sensing or sensors to monitor climatic conditions, soils or yield, farmers can detect temporal and spatial variability across their fields to selectively treat their crop, either manually or through technologies that adjust their behaviour in response to the gathered data. Much of the focus has been on variable rate application (VRA) of inputs based on yield and soil monitoring (McBratney et al., 2005). VRA can either be controlled through maps developed from the collected data or through measurements gathered by real-time sensors (Zhang, Wang, & Wang, 2002).

Precision agriculture originated in the EU, US and Japan in the early 1980s, in part driven by the need to comply with environment standards (McBratney et al., 2005). It later spread to other countries with large-scale agricultural production, such as Australia, New Zealand, Argentina and Brazil. Some applications are also found in other developing countries, mainly to ensure the quality of high-value export crops, such as coffee and bananas in Cost Rica, sugarcane in Mauritius or oil palm in Malaysia (Autrey, Ramasamy, & Ng Kee Kwong, 2006; Mondal, Basu, & Bhadoria, n.d.; Oberthür, 2006; Zhang et al., 2002). China is also investing in the development of precision agriculture technologies through dedicated research centres and test sites (Wang, 2001).

The uptake of precision agriculture technologies and M2M applications more generally has been limited in developing countries which accounted for just 1.5% of global usage of M2M applications in 2012 (Arab, 2012). Many of the high-tech agricultural applications used in industrialised and a few developing countries are unlikely to be appropriate in this context given low levels of literacy, limited access to equipment and small landholdings (ICT Update, 2006). On the business side, M2M usage has also been hampered by the cost of M2M modules, the lack of open-standard platforms for M2M development, and a missing M2M strategy from mobile operators in these markets (Arab, 2012).

However, the rapid spread of mobile phones and networks as well as advances in the IoT and related technologies could lead to technology applications that are better adapted to the needs and capacities of small-scale producers. Several examples of such lower-tech applications can be found in developing countries that facilitate the adoption of agricultural technologies, although mostly on a small scale. The greatest potential of IoT is likely to lie in the area of *information & learning*. For instance:

- Data collection applications for mobile phones, such as *EpiCollect*, *Magpi* (formerly *EpiSurveyor*) and *ODKCollect*, employ geo-tagging (using the phone's GPS) to gather location-specific data. For instance, Makerere University in Uganda is using ODK Collect to automatically diagnose and monitor the spread of cassava mosaic disease (Quinn, Leyton-Brown, & Mwebaze, 2011). Data about the state of the plant is collected by surveyors, extension workers and farmers through GPS-and camera-enabled phones, and classified using computer vision techniques. The information is then used to generate maps showing the extent of the disease outbreak.

- In Kenya, GPS tracking devices attached to one cow in the herd enable livestock owners to monitor the movement of their animals and recover stolen cattle (Africa Agriculture News, 2013). The Dutch company Sparked has developed sensors implanted in the cows' ears that not only track movement, but also monitor the animal's vital signals and eating habits (Jefferies, 2011).
- Modern ICTs are being used to simplify mapping procedures and make maps more accessible to local communities. Examples include a micro-mapping tool for smartphones which can be employed to map small geographic features using camera-and-speech-based methods (Frommberger, Schmid, Cai, Freksa, & Haddawy, 2012). Due to the comparatively simple interface and workflow, such tools are designed to be used by local stakeholders, for instance to improve and monitor agricultural activities. Another example is participatory three-dimensional mapping which draws on the knowledge of local communities to locate features on a 3D terrain model which are then merged with GIS-generated data.[11] In India, a GIS-based tool was developed to help villagers better prepare for drought (Kumar, Nagarajan, Kesava Rao, & Balaji, 2007). The tool uses data from satellite images, local water conditions and rainfall records to generate maps highlighting drought-prone areas and predict rainfall in the upcoming season. Information is disseminated to local communities via Internet-connected rural knowledge centres.
- The Syngenta Foundation's *Farmforce* tool uses cloud-based technologies to collect data from farmers via mobile phones (including SMS and geo-referenced farm data) which is integrated into the supply chain management system (Wills, 2013).

The IoT could also facilitate access to *financial services*, in particular the provision of insurance to small-scale producers. In Kenya, for instance, insurance companies are deploying M2M technologies in Kenya to manage micro-insurance schemes for crop and livestock producers, including *Kilimo Salama* which uses data from weather stations to trigger insurance pay-outs in case of severe weather events via mobile phones and ILRI's livestock insurance which calculates pay-outs for livestock losses using satellite data (NDVI) to monitor forage scarcity.

Possible applications to facilitate *access to agricultural inputs* (e.g. seeds, fertilizer, water, electricity or labour) may be more limited. One example is the m-services Nano Ganesh, developed by the Indian company Ossian Agro Automation, which allows farmers to control water pumps remotely using their mobile phones, including monitoring the availability of electricity, switching the pump on and off and getting alerted in case of attempted theft.[12]

With regard to improving *access to output markets*, M2M devices are already being deployed in supply chain management. In Kenya, Virtual City's *Agrimanagr* and *Distributr* systems use mobile phones to collect data when farmers deliver the produce, e.g. weight and location (through GPS), and track the produce throughout the chain to the processing plant.13 The data is uploaded to the cloud through the cellular network and can be accessed by headquarters. In Ghana, SAP uses barcodes linked to a famer's profile to record produce deliveries and upload the information to a central system via mobile phones.

[11] www.iapad.org
[12] www.nanoganesh.com
[13] www.virtualcity.co.ke

2.3 Capitalising on networks and large user base

The ubiquity of cellular networks coupled with the expanding reach and diversity of mobile devices will offer significant opportunities to collect, disseminate and exchange data and knowledge. ICT trends to watch in this context are 'big data', crowd-sourcing and social networks.

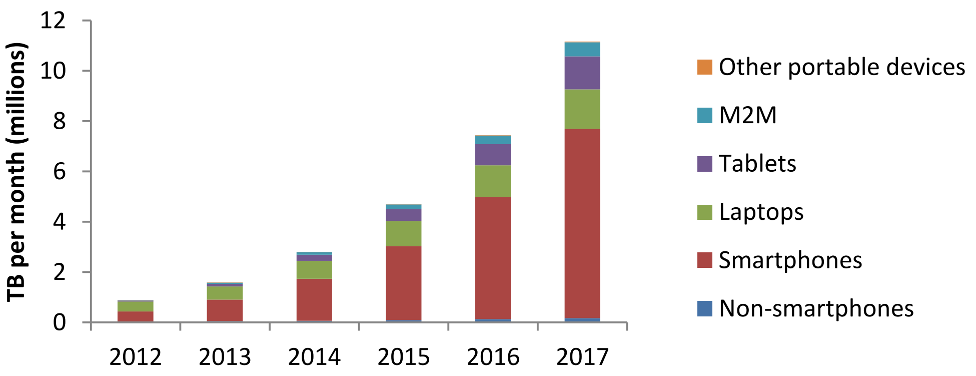
2.3.1 Big data

The world's stock of digital data is thought to be doubling every 20 months (Bughin, Chui, & Manyika, 2013). This growth has given rise to the concept of 'big data', but the term is not clearly defined in the literature. Manyika et al. (2011, p1) describe big data as "datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyse", but refrain from putting a number on the data volumes. The Global Pulse – an initiative launched by the Executive Office of the United Nations Secretary-General in 2009 to explore how digital data and real-time analytics technologies can assist policy-making – identifies four broad digital data sources as relevant for global development (Global Pulse, 2012):

- *Data exhaust*, i.e. passively collected transactional data from people's use of digital services such as mobile phones or mobile payments,
- *Online information*, i.e. web content such as news media and social media interactions, web searches or job postings
- *Physical sensors*, i.e. satellite or infrared imagery of e.g. changing landscapes, traffic patterns, light emissions, urban development and topographic changes,
- *Crowd-sourced data*, i.e. information actively produced or submitted by citizens through mobile phone-based surveys, hotlines, user-generated maps etc.

Personal mobile devices are contributing significantly to the growth in data volumes, in part due to the diversification of wireless devices, the growth in average traffic per device and the expansion of 4G networks (Cisco, 2013). The *Cisco Visual Networking Index* predicts that smartphones (and to a lesser extent high-end feature phones) will be the main source of mobile data growth (ibid). While smartphones made up only 16% of handsets in use globally in 2012, they represented 92% of handset data traffic and 44% of global data traffic. By 2017, the share is expected to increase to 68% (Figure 3). In terms of data traffic generated per device, smartphones produced about 50 times more traffic than feature phones in 2012 which is expected to increase to 86 times by 2017 (Table 1). Other devices will also contribute to the growth in data traffic, though to a lesser extent. While M2M devices are estimated to increase 24-fold during the five-year period, their contribution to global data traffic is only expected to increase from 3% to 5%. In terms of content, much of the data growth will be driven by mobile video which is projected to account for two thirds of mobile data traffic by 2017 (Cisco, 2013).

Figure 3: Global Mobile Data Traffic 2012-2017 (by device)



Data source: Cisco (2013)

Table 1: Per device usage growth 2012-2017

	Average traffic per device (MB per month)		Comparison with non-smartphone*	
	2012	**2017**	**2012**	**2017**
Non-smartphone	6.8	31		
M2M Module	64	330	9	11
Smartphone	342	2,660	50	86
4G Smartphone	1,302	5,114	191	165
Tablet	820	5,387	121	174
Laptop	2,503	5,731	368	185

* x times monthly basic mobile phones data traffic
Data source: Cisco (2013)

While smartphones will dominate data traffic in terms of volumes, the data generated by more basic phones may be particularly useful for developing countries. Indeed, the MIT Technology Review identified 'big data from cheap phones' as one of ten breakthrough technologies in 2013 (Talbot, 2013). While most of these phones are only used for calls and SMS, data from cell phone towers can offer insights into people's movements, calling habits and social connection. Wesolowski et al. (2012), for instance, used data from cell phone towers in Kenya to monitor human travel and thereby identify importation routes for malaria through movements of infected people. Useful data could also be obtained through mobile payment systems which combined with phone records could be used to study employment trends, social tensions, poverty, transportation and economic activity (Talbot, 2013). In the agriculture sector, such data could help, for instance, to assess which markets farmers visit how often and when, or how they make agricultural purchases.

The willingness among operators to share data from cell phone towers appears to be growing. In 2012, Orange released 2.5 billion anonymised records from Côte d'Ivoire and, in cooperation with the University of Leuven and the Massachusetts Institute of Technology, issued the Data for Development Challenge to ask the scientific community how big data could contribute to the development of an emerging country.[14] Examples of submissions included models to monitor the distribution and risk of the spread of disease, models for urban planning and road transport, and optimization models of energy consumption and emissions of $C0_2$. One submission also used phone records for poverty mapping (Smith, Mashhadi, & Capra, 2013). Analysing antenna to antenna traffic, the researchers found that certain proxies (i.e. outgoing volume and duration of calls, flow between regions, diversity of connections with other regions and level introversion of a region) may be suitable to estimate poverty levels of different regions.

In addition to analysing incidentally collected data from cell phone towers, mobile connected devices are also valuable sources of specifically collected data e.g. through data collection tools or obtained through the various IoT technologies outlined above (e.g. RFID tags, sensors, data collection apps or GPS tracking devices). Cloud-based services will facilitate the storage and analysis of such data, including combining data collected through mobile devices with other data stored in public databases. Mobile devices can then be used as channels to disseminate the analysed data, e.g. through SMS- or app-based m-services. A bottleneck in this regard is likely to be training the people and developing the tools capable of making sense of the huge amounts of data (Manyika et al., 2011).

[14] www.d4d.orange.com

2.3.2 Crowdsourcing

Information gathering and sharing can also capitalise on the extensive virtual networks created through modern ICTs. Information collection can be done through a process commonly referred to as crowdsourcing where data collection or other tasks are carried out by an undefined group of ICT users either for free or against payment (Estellés-Arolas & González-Ladrón-de-Guevara, 2012). The Kenyan company Ushahidi is a prominent example of this approach.[15] *Ushahidi* has developed an ICT platform for crowdsourcing and automatically analysing information obtained from SMS, email, Twitter and the Internet. The analysed data is then displayed through maps and dynamic timelines. The system was first used to monitor incidences of post-election violence in Kenya in 2007 and has since then been applied in numerous countries and sectors around the world.[16] The Bangladeshi NGO BRAC, for instance, used *Ushahidi* to poll and map the development priorities of around 175'000 Bangladeshis for the next 15 years (May, 2013).

Another example of a crowdsourcing application is the Boston-based *Jana Mobile Rewards Platform*[17] (formerly *txteagle*) which collects data from users in emerging markets by sending out surveys that can be completed via mobile web or desktop in return for mobile airtime. The company claims that it can reach close to 3.5 billion people through its partnerships with 235 mobile operators in over 100 countries. The tool has mainly been used by international companies, such as Pond's, Unilever, Danone and Wrangler, to undertake market research. Jana is also collaborating with the UN to collect data, for instance to conduct a global survey of 90,000 mobile subscribers on well-being and interconnectedness in over 30 countries (Global Pulse, 2013). Jana estimates that the UN's use of their system for data collection has reduced data collection costs by 80% and collection time by 65%.

In agriculture, crowdsourcing could be used, e.g. to monitor crop disease outbreaks, gather information about input suppliers and prices, or collect information about crop damage from severe weather events for insurance purposes. A few examples can be found:

- The above-mentioned monitoring tool for cassava disease in Uganda relies on a network of agricultural extension workers and farmers to report possible incidences of diseases.[18]
- In Laos, the *Poverty Reduction and Agricultural Management – Knowledge Sharing Network* (PRAM-KSN), which is targeted at extension workers, offers a platform for users to upload local stories that can be retrieved by extension workers and a function where extension workers can ask for solutions to a certain problem from the entire user base (Ei Chew, Sort, & Haddawy, 2013).[19]
- The *Community Knowledge Worker Programme* in Uganda engages local CKWs who collect information, such as plant diseases incidences, smallholder farmers' potential to supply to markets or adoption of expert advised techniques such as fertilizer, from farmers using mobile data collection tools.[20]

Such initiatives can at time be challenging to implement (de Carvalho, Klarsfeld, & Lepicard, 2011). Lower income groups are often be difficult to engage, for instance because of the nature of the surveys or the technologies used (as in the case of Jana). Intermediaries may be required to bridge the gap between farmers and the mobile application (as in the case of *CKW*). Crowdsourcing initiatives also need to develop the capacity to compile data collected from different countries, e.g.

[15] www.ushahidi.com
[16] See community.ushahidi.com/deployments for an overview of deployments
[17] www.jana.com
[18] cropmonitoring.appspot.com
[19] pramksn.iist.unu.edu/en
[20] www.ckw.applab.org

through the use of cloud computing. Finally, to ensure quality of data, the information collected needs to be verified which can be cumbersome for widely disbursed or anonymous data sources.

2.3.3 Social networking and learning

ICTs also offer opportunities for development by supporting social networking and learning (von Braun, 2010). *Facebook*, for instance, probably the most well-known example of a social networking platform, is rapidly spreading around the world. In October 2012, Asian users constituted the largest share (28%) with 269 million users (TechLoy, 2012). Africa's share of users was small at just 5%, but also growing most rapidly. To promote usage in emerging economies and adjust to local technological conditions, *Facebook* has launched the 'Facebook for Every Phone' initiative which offers a simplified version of Facebook that can be accessed through feature phones (Goel, 2013). The first field study of *Facebook* usage in a developing country (Kenya) found that interest in using *Facebook* was generally high, but constraints such as the cost of Internet usage, limited access to computers or smartphones and gaps in electricity supply still hinder widespread participation (Wyche, Yardi Schoenebeck, & Forte, 2013).

In addition to international platforms, national and regional platforms are also emerging. *MXit* South Africa, for instance, prides itself on being Africa's biggest social network with 50 million users. Highlighting the potential uses of such networks, the most popular applications among South Africa's predominantly 15-35 year old *MXit* users include weather forecasts, a spelling game, a mobile platform for classified ads and trading, and an Internet browser (Mxit, 2012).

A number of initiatives are also emerging in the agricultural sector which are using ICTs to support social learning among farmers. In India, for example, *Digital Green* recruits farmers to record videos with testimonials and demonstrations of farming techniques, market linkages or government policies which are distributed via the website and shown in villages using battery-powered projectors.[21] Similarly, as part of the *Lifelong Learning for Farmers* initiative female livestock producers record audio learning modules for dissemination among fellow livestock producers via mobile phones. Farmers participating in *Sauti ya wakulima* in Tanzania publish images and audio which are recorded with smartphones on the Internet. As noted above, *PRAM-KSN* facilitates social learning through information exchange and collective problem solving among extension workers via the Internet.

3 Scenarios for the Evolution of Technology Trends and M-services

This section describes two possible outcomes of the three technology trends discussed above (diversity of devices, Internet of Things and capitalising on networks) and assesses how these could affect m-services provision: (1) Status Quo (technological developments remain on a similar level as today) and (2) Big Leap (significant advance in the technology trends). Figure 4 summarizes the main characteristics of the two scenarios. The implications specifically for farmers are evaluated in the following section.

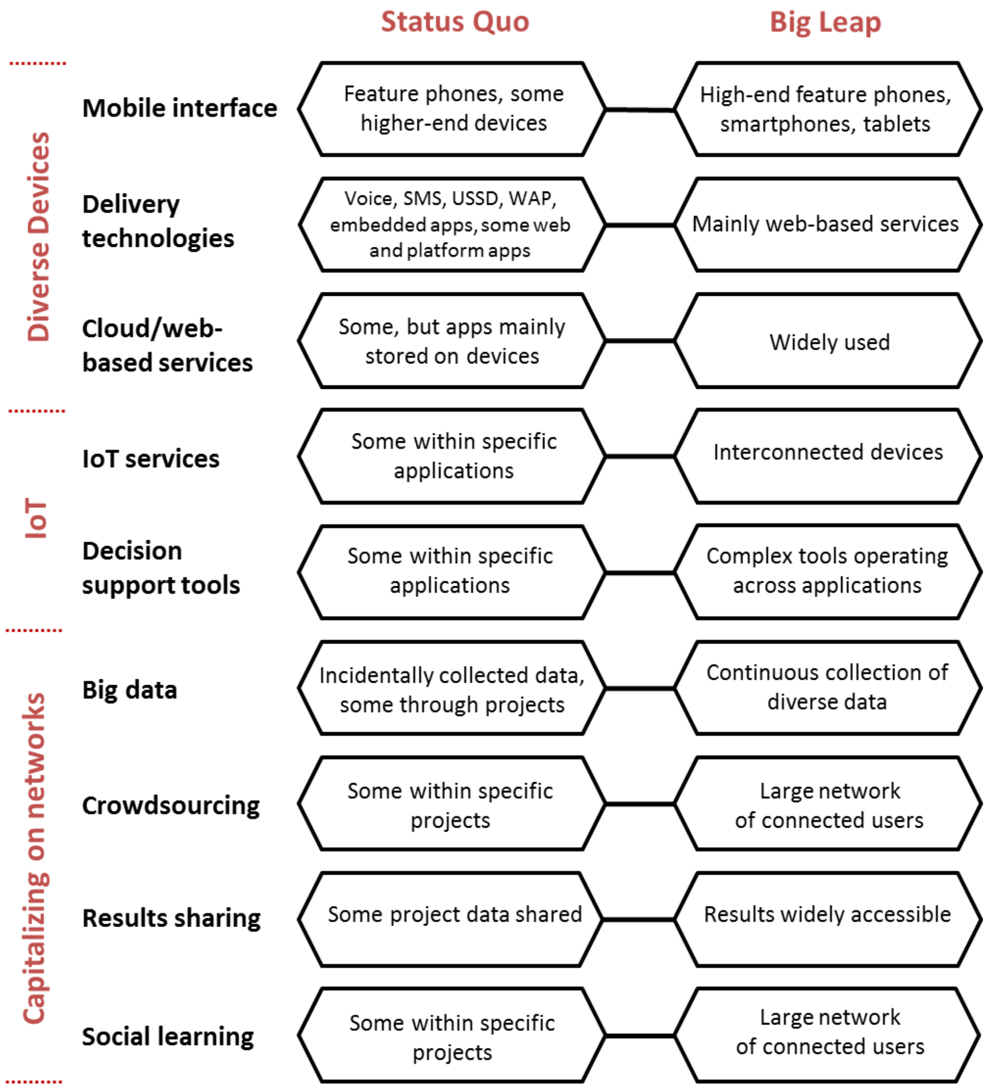
For each scenario, different assumptions are analysed related to six dimensions, i.e. the usability of resulting m-services, their affordability, power requirements, network capacities, the nature of service providers and the innovation environment. The dimensions were identified based on an extensive review of the literature (including blogs and other websites) as summarized in the previous section. The focus is on the utility of and implications for smallholder farmers as well as other farmers in developing countries.

[21] www.digitalgreen.org

The scenario analysis is based on three overarching assumptions:

- 2G networks are available (given that they already cover over 90% of the global population)
- Users have access to electricity for charging their mobile devices (either through direct access to the electricity grid or, more likely, alternative sources such as recharge shops or solar power).
- International connectivity is available.

Figure 4: Two scenarios for the possible evolution of the technology trends



3.1 Possible scenarios

Scenario 1: Status quo

Outcomes of technology trends

Diverse devices

Feature phones dominate mobile phone usage among farmers. High-end feature phones are also starting to spread, but the share of smartphones remains low while mobile PCs and tablets are hardly available. Voice, SMS, USSD, WAP and embedded apps are the main delivery technologies, complemented by a few platform apps and web-based services. Some cloud services are used for specific applications, but most of the applications are stored on the device itself, either as embedded apps or downloaded from traditional app stores.

Internet of Things
A few small-scale m-services are using the IoT for specific applications linked to a limited number of devices, mainly in the area of supply chain management and data collection through GPS-enabled phones. Simple decision support tools to help make sense of the collected data are built into the individual applications.

Big data and social networking
Incidental data of mobile phone usage is collected by the MNOs and to some extent released for research purposes, but the results are not shared with those providing the data. In addition, crowdsourcing of data is carried out for specific projects among limited groups of users, mainly via SMS (from individual farmers) or platform and web-based applications (through intermediaries working with farmers). Some of the results are shared with the data providers through simple reports, but most is used for project planning or to share with others. Social networking sites are mainly accessed through SMS and down-sized web-versions, primarily for recreational use. Some mobile device-enabled social learning takes place, albeit limited to specific projects.

Assumptions

Usability
M-services offered through feature phones are relatively easy to use for farmers – including older farmers with less exposure to modern ICTs – since the devices are similar to the basic phones they have been using for some time. However, as services and delivery technologies become more sophisticated, a higher degree of literacy and technological experience is required, thus limiting the use of these services by illiterate and less tech-savvy farmers. The small display of most feature phones (in particular for web-based services that require a browser) and the use of simple delivery technologies (such as SMS or USSD) restrict the amount and complexity of information that can be displayed. Opportunities for users to interact with the service provider are limited.

Affordability
The initial cost of lower-tech phones is generally low, though increasing with sophistication. The prices of smartphones are approaching those of high-end feature phones, but are nevertheless expensive for farmers to purchase. Tablets are often not affordable by individual farmers and have to be supplied (e.g. by the service provider) or purchased communally (e.g. by a cooperative). Usage costs are generally low for simple delivery technologies, such as SMS or USSD, but increase with sophistication of the service, in particular if data transfer is required (although data usage is fairly low because of the simplicity of the applications). Data plans remain expensive in many developing countries. M2M devices are supplied by the service provider as a package due to the high cost of purchasing the devices and setting up the necessary infrastructure.

Power source
Lower-tech mobile phones have a relatively long battery life for basic uses. However, battery usage increases with the technical capacities of the device (e.g. a colour screen) and the complexity of the services (e.g. with data transfer), thus restricting the utility of such phones and services in areas with limited opportunities to charge the phone (e.g. due to the distance to the nearest recharge shop). The lack of reliable access to electricity in many rural areas also limits the widespread use of M2M devices. While some M2M applications are using solar panels to obtain electricity, other alternative sources, such as generators, are not cost-effective because of the small scale of M2M usage.

Network
Lower-tech phones as well as some smartphones and tablets are using the existing 2G networks, but more sophisticated applications, in particular those involving Internet access, require faster 3G networks. While 3G networks have expanded into rural areas, urban-rural access gaps remain in terms of coverage and actual network speeds. Obstacles to the expansion of faster networks in rural areas are the high cost of building the new infrastructure required for 3G networks and lack of electricity for the base stations. The networks are mainly traditional mobile, licensed spectrum networks.

Service providers
Many m-services are provided by MNOs which are mainly targeting the middle- and high-income markets to reach financial sustainability. External service providers, including local start-ups, are also offering m-services, usually in collaboration with MNOs to capitalise on their customer base, sales outlets and payment systems. As a result, many m-services are restricted to users of one network. External providers often find it difficult to scale their services and reach financial sustainability, in particular if targeting the lower-income markets with limited purchasing power, which leads to high failure rates in the long run.

Innovation environment
Funding for local companies is mainly available through venture capitalists ('angel investors') from the US and Europe. The government supports local innovation through policies, but offers little concrete support such as infrastructure or financing. Some of the leading ICT countries have established local innovation networks but exchange between networks in different countries is limited.

Scenario 2: Big leap

Outcomes of technology trends

Diverse devices
Higher-tech devices are widely adopted, especially high-end feature phones, smartphones and tablets. These devices are particularly attractive for younger, more technologically experienced users. Adoption is driven by falling device prices due to greater competition in particular from emerging economies such as India and China, cheaper data plans as MNOs move from voice to data as their main source of revenue, and the extension of broadband networks which have become more cost-effective due to higher demand. Lower-tech phones may be used as secondary phones (e.g. as one of several in a household or for basic uses). The widespread use of higher-tech devices has created a positive feedback loop where m-service providers respond to the new technological capacities by offering more sophisticated services which in turn further stimulates demand for and supply of higher-tech devices and associated infrastructure. As a result, the majority of m-services are accessible through web-based applications supported by cloud computing to offer sophisticated services that are independent from platforms and devices and accessible to multiple users.

Internet of Things
Users operate in an interconnected world where personal mobile devices are linked up with other mobile devices (including M2M). Complex decision support tools operating across applications enable farmers to make use of analysed data, including the data they collect themselves and data from other interconnected users and data sources.

Big data and social networking
The widespread adoption of higher-tech devices and related m-services yields a wide range of diverse data which are continuously being collected and analysed, both incidentally and through

specific data collection efforts. The process is assisted by cloud services (accessible through cheaper and higher quality networks) which allow for data gathering and analysis from different devices and countries. The data collected through mobile devices is combined with other publicly available data. The results of the data analysis are accessible to data providers and others interested in the data through interactive interfaces using diverse visualisation methods. Large networks of connected users can be engaged for crowdsourcing of data, collaborative problem solving and learning, either within a certain limited area or worldwide. As data volumes grow and become accessible to a wider range of users, issues of data privacy are gaining in importance to ensure that users continue to willingly share their data.

Assumptions

Usability

Smartphones and tablets are better suited for sophisticated services and web-based applications. However, the devices are also more complex to use because of the novel interface which poses a barrier in particular for older farmers and those with limited experience in the use of ICTs. At the same time, they offer more diverse features to display content, for instance using images instead of letters and a touchscreen instead of a keyboard, thus making them more accessible to illiterate users (after training). Service providers have to balance the simplicity of the interface and the complexity of the information and services provided. Different strategies are used to make the services accessible to a wider audience, for instance by engaging support (as in the example of the CKW initiative in Uganda) or by combining different ICTs (such as mobile devices and radio). In addition, younger family members are functioning as intermediaries between the m-service and older farmers by utilising the service on their behalf (including remotely, for instance rural youth who have migrated to the city for work).

Affordability

Prices of higher-tech phones have come down due to their widespread use and stronger competition from manufacturers in emerging economies. Tablets have also become cheaper although they remain relatively expensive compared to mobile phones. The pressure to reduce prices has come at the expense of device quality, e.g. in terms of robustness and battery life. Higher-quality mobile devices remain expensive for low-income users. Usage costs have increased due to the extensive use of data-driven services, in particular web-based services, but increased demand has led to a drop in the cost of data plans available for users. M2M devices have become cheaper due to technological advances and higher demand. As a result, farmers can purchase and combine a range of devices from different manufacturers and service providers.

Power source

Technological advances have improved battery lives of all phones. In addition, the growth in mobile connected devices has increased the demand for electricity which has made investments in power supply in rural areas more economical. However, higher-tech phones and tablets still require considerably more battery power than lower-tech phones. Also, some manufacturers compromise on the quality of the battery to reduce the price of smartphones and tablets. These constraints limit their utility for users without easy access to electricity. Power consumption of the M2M devices has been reduced through technological advances and many M2M devices are now able to generate their own energy from environmental elements.

Network

3G and 4G networks have expanded into many rural areas in developing countries through the expansion of microwave and optical fibre infrastructure in response to high demand for fast and reliable network access. 2G networks continue to operate for lower-tech phones and many M2M devices. HetNets have been established to overcome constraints related to spectrum availability and data capacities. Electricity to power the networks are provided through grid expansion and innovative solutions, such as diesel generator-battery hybrids, green power or the BRCK.

Service providers
M-services are mainly developed by external providers that can offer services across networks, phone manufacturers and platforms. The role of MNOs has shifted to providing infrastructure and supporting the marketing of services in collaboration with the providers. International and local providers are both offering services. South-South partnerships help to develop and market locally adapted and cost-effective services. Service providers target different user segments with different types of services depending on the users' needs and capacities. Cross-subsidisation through differential pricing helps to make services for lower income users financially sustainable.

Innovation environment
Investment for local service providers is available from a range of investors, including local investors and investors from emerging economies. While m-services development and delivery are mainly driven by the private sector, governments provide active support for the local innovation scene, for instance through start-up grants, co-funding, infrastructure development, policies and the provision of content (e.g. weather or price information). Local innovation networks are flourishing in many countries, offering advice and infrastructure support to local companies. These networks are connected to similar networks in other countries, supported by social networks, conferences and competitions.

3.2 Implications for m-service provision to farmers

The two scenarios would have different implications for the provision of m-services to promote agricultural technology among farmers in developing countries. The types of m-services are grouped into four categories: information and learning, input markets, financial services and output markets. Within these categories, the following implications could be envisaged:

Information and learning

Scenario 1: Status Quo
Farmers access information mainly on feature phones through simple delivery technologies, such as SMS or voice recordings, which limits the amount and complexity of information that can be disseminated. Web- and cloud-based services are mainly accessed through shared devices, e.g. owned by farmers' cooperatives. The use of mobile devices for training purposes is largely confined to the one-way provision of information that can be accessed through simple delivery technologies. M-services also support social learning among farmers, but only within dedicated projects. Publicly available social networks are too general to lend themselves to issue-specific information exchange and learning.

Scenario 2: Big Leap
Higher-tech devices and faster networks allow m-services providers to use diverse media to disseminate information about farming practices, such as video, voice recordings, images or longer text. The sophisticated interfaces also facilitate interactive training on agricultural production and marketing for farmers. Specifically designed interface increase the reach of m-services to illiterate and less technologically experienced farmers although training is still needed to familiarise them with the new features of higher-tech devices. These services benefit in particular women farmers who otherwise may not have the time, resources or courage to participate in agricultural training activities. Large virtual networks of farmers that span across countries and borders are used to exchange information and learn from other farmers.

Lower quality smartphones are widespread among famers, but feature phones are still used for basic mobile services (such as voice calls and SMS) by low-income farmers and as secondary phones by higher income farmers. Limited access to electricity also remains a constraint to the adoption of more sophisticated devices in some rural areas. Higher quality smartphones and tablets are mainly shared among farmers' groups.

Farmers are using IoT services to assist with site-specific management of their fields, monitor the development of their crops, adjust their agricultural practices in response to the data and track the sales of the produce. The information they gather is complemented by other information to help with planning, such as weather forecasts or price information for inputs and outputs.

Input markets

Scenario 1: Status Quo
M-services facilitate input markets by offering access to information about input prices and input sellers in the vicinity.

Scenario 2: Big leap
In addition to providing information about prices and sellers, m-services help farmers to access inputs by facilitating virtual networks of sellers and buyers.

Financial services

Scenario 1: Status Quo
M-payments are being integrated with banking services to allow farmers to transfer money directly from their bank accounts. However, the low uptake of higher-tech devices restricts the complexity of services that can be offered due to the small interface and limited use of web-based services.

Some insurance companies are using IoT devices to operate insurance schemes, but the initiatives largely remain small-scale and only insure against a few types of damages because of the technological limitations and lack of integration of available IoT devices

Scenario 2: Big Leap
Farmers can integrate different financial services through more sophisticated banking applications, including making payments, monitoring loan repayments and managing their savings.

The growing sophistication and integration of IoT devices, such as weather stations, soil sensors, tracking devices or satellite imagery, enable insurance companies to scale up and expand the scope of insurance schemes for large numbers of dispersed farmers. M-payments allow farmers to easily obtain insurance and receive insurance pay-outs.

Output markets

Scenario 1: Status Quo
M-services are mainly used to provide price information to farmers. Data is collected by service providers and only available for a limited number of markets. The information can be accessed by subscribers of the service.

Virtual markets are also being developed, but struggle to overcome issues of trust. Human intermediaries to verify produce quality are often required which limit the scale that can be reached.

IoT devices are being used to manage supply chains, including to source from large numbers of smallholder farmers. A few m-services are also using GPS-enabled phones to gather information about agricultural production, but applications remain small-scale and data sharing is confined to registered users.

Scenario 2: Big Leap

Price information is collected by service providers as well as crowd-sourced from sellers and buyers, thereby expanding the range of crops and markets for which price information is available. The information is collected and analysed through cloud-based software platforms, which in addition to spot prices also offer information about price trends. The information is widely available to interested users.

Farmers and buyers are connected through virtual marketing networks. Different technologies (including IoT technologies) are being used to help build trust among users, including images of the produce, tracking of produce deliveries, ratings of transactions on websites and m-payment facilities. The data collected through these virtual transactions allows for more strategic investments into transportation routes and storage facilities.

4 Conclusion

Most of the agriculture-related m-services available in to farmers in the developing world are using simple delivery technologies, such as SMS and voice-based systems. Mobile technologies are a fast evolving field, however, and current technology trends offer numerous opportunities to develop more sophisticated m-services for farmers. Today, users have access to a much greater variety of devices, including smartphones and tablets, which enable the dissemination of more complex information, easier use of interactive services and the ability to run advanced software on relatively simple machines through web-based services. At the same time, ICTs are becoming more ubiquitous and interconnected through expanding mobile networks, allowing for the collection and procession of large amounts of data to assist in farming and the creation of social networks for information exchange and learning.

However, many of the new technological opportunities have not yet been realised in practice – neither in industrialised or in developing countries. It will be important to understand which of these technologies can realistically be applied to promote agricultural development in developing countries (i.e. what are the obstacles and what would be needed to remove them) and which are most relevant in the given context (i.e. what is the demand). M-service developers will also need to ensure that their services continue to cater for a broad range of users rather than focusing overly on technologies that may not be within the reach of less-resourced farmers.

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