Chapter 9
Agricultural Service Delivery Through Mobile Phones: Local Innovation and Technological Opportunities in Kenya

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Abstract The rapid spread of mobile phones across the developing world offers opportunities to improve service delivery for smallscale farmers. International and local companies have already started to capitalize on these opportunities although many mobile phone-enabled services are still at an early stage. Kenya has emerged as a leader in m-service development in Sub-Saharan Africa. This chapter assesses the key factors that have helped the local innovation scene to emerge and reviews existing agricultural m-services that provide Kenyan farmers with access to information and learning, financial services, and input and output markets. The potential impact of m-services is illustrated with the example of the price and marketing service M-Farm. Finally, the chapter assesses current mobile technology trends to offer an outlook on potential future applications.

Keywords Mobile phone • Kenya • M-service • Innovation • Smallholder farmer

Introduction

Kenya has emerged as a frontrunner in information and communication technologies (ICT) in Sub-Saharan Africa. The government has been actively supporting the ICT sector as one of the key drivers of economic growth. In addition to large international firms that are setting up offices in Nairobi, such as Nokia, IBM and Google, local start-ups have also been expanding rapidly. Kenyan entrepreneurs have greatly benefited from the growth of the local innovation environment in recent years, including the establishment of several innovation hubs, a growing pool of human resources, and access to finance from private investors. An increasingly well-connected customer base and improving infrastructure are also helping entrepreneurs to market their services.

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As a result, Kenyans have access to a growing number of services through their mobile phones (m-services). The mobile payment system *M-Pesa* is one of the most successful mobile payment systems in the developing world. M-services are also available in other sectors, such as education, health and entertainment. In the area of agriculture, mobile phones could be particularly helpful in extending the reach of services to rural populations by facilitating communication that is not restricted by distance, volume, medium and time (von Braun and Torero 2006). Several m-services are already offered to Kenyan farmers, including information, insurance and marketing services. Many of these are provided by local companies, although most remain at a small scale.

This chapter outlines the key factors that have supported the growth of the Kenyan m-services sector. It reviews the agricultural m-services currently available and presents a case study of one such service, *M-Farm*, which offers price information and marketing services to Kenyan farmers. The chapter concludes with a brief assessment of current mobile technology trends to provide an outlook on potential future applications in the agriculture sector.

Kenya's ICT Ecosystem for Local Entrepreneurs[1]

Opportunities...

> Kenya is rising fast as a technology powerhouse on the African continent and more so in Sub-Saharan Africa. (Afrinnovator 2012, p. 1)

Network Infrastructure

Kenya's growing ICT ecosystem is making the country an attractive place for local entrepreneurs to develop and deploy m-services. The first sea cable to link Kenya internationally came online in July 2009, thereby offering a faster and cheaper alternative to satellite connections (McCarthy 2009). Since then, three additional sea cables have been connected to landing points in Mombasa (Fig. 9.1) and another three cables are planned (Mbuvi 2013). Terrestrial fiber optic cables are starting to reach into all parts of Kenya and are expected to expand further following an agreement in June 2012 between the Chinese and Kenyan governments to provide financing for the National Optic Fiber Backbone Infrastructure (Wahito 2012). The government has supported this infrastructure expansion through various regulatory measures and financing (see below).

[1] Unless otherwise stated, this section draws on interviews with key informants in Nairobi carried out in April–June 2012.

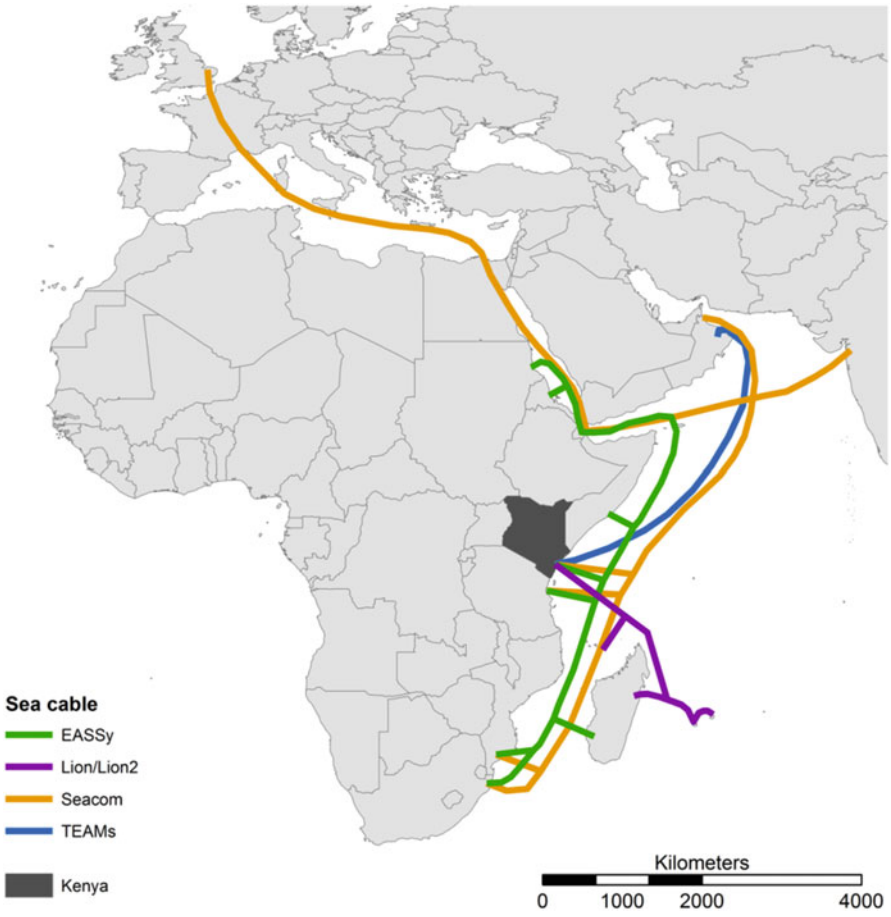

Fig. 9.1 Map of sea cables to Kenya (Data source: UbuntuNet Alliance (as of November 2012)) Cartography: Heike Baumüller

A Supportive Innovation Environment

One of the key factors driving the expansion of Kenyan technology start-ups is the innovation environment, which has grown in particular over the past 6–7 years. Several innovation hubs have been set up, led by the iHub and followed by others, such as the m:lab, the Nailab, the 88mph Garage or @iBizAfrica, which offer a space and infrastructure for developers, mentorship from more experienced entrepreneurs, and opportunities to interact with investors, fellow developers and business partners. The hubs have also helped to strengthen the connectedness of the local tech community, which Eric Hersman, co-founder of the iHub, believes has given Kenya a crucial competitive advantage over other countries (Hersman 2012). These innovation spaces were mainly driven by visionary entrepreneurs and

tech developers with support from foreign investors or donors. Companies, such as Intel, Nokia and IBM, are also starting to link up with or invest in their own innovation spaces in Kenya.

Kenya has also been attracting investor attention "as a hub for ICT innovation" (Deloitte 2012, p. 17). Much of the interest has come from non-Kenyan investors and, in particular, so-called 'angel investors' who are willing to support start-up ideas and talents. The Savannah Fund, for instance, was launched in mid-2012 as a seed capital fund specializing in $25,000–$500,000 (US) investments in early stage high growth technology (web and mobile) start-ups in Sub-Saharan Africa.[2] Financing for Kenyan start-ups is also available through numerous competitions, such as Pivot East, IPO48, Apps4Africa, Google Apps Developer Challenge or the Orange African Social Venture Prize, in which developers can win seed funding of $10,000–$25,000 (US). In particular, the results of Pivot East, a competition for developers from East Africa in which Kenyan entries continue to dominate the winners' list, exemplify the success of Kenyan developers in raising start-up funding (Sato 2013).

The ICT sector can also draw on a growing pool of human resources and a young generation that is increasingly willing to take the risk of setting up their own technology companies. Training opportunities are expanding, notably through eMobilis, the first Mobile Technology Training Academy in Sub-Saharan Africa. The academy was established in 2008 and teaches both IT and business skills to enable young people to set up their own technology businesses. The graduates are highly motivated by seeing other technology companies succeed, such as Facebook and Instagram internationally and local start-ups such as *Ushahidi*,[3] *Kopo Kopo*[4] or *M-Farm*. The private sector is also increasingly tapping this potential, such as in the case of Safaricom, which, in collaboration with the @iLabAfrica of Strathmore University and Vodafone, has set up the Safaricom Academy where students can earn a Master of Science in Telecommunication Innovation and Development.

Government Policy

The development of the ICT sector has also been promoted by the Kenyan government. The sector has emerged as a key driver of economic growth, showing an annual growth rate of around 20 % and adding 0.9 % to annual GDP growth between 2000 and 2010 (World Bank 2010). To support the sector, the government adopted a national ICT policy in 2006 and set up an ICT Board in 2007. While the focus was initially on marketing Kenya as a hub for outsourcing ICT-related

[2] www.savannah.vc.

[3] A crowd-sourcing technology for collecting, visualizing and interactively mapping information (http://ushahidi.com).

[4] A platform to enable small and medium businesses to accept mobile payments and build relationships with their customers (http://kopokopo.com).

business, the government is also stepping up efforts to support local technology entrepreneurs. For instance, the ICT Board has launched the Tandaa grant which promotes the creation and distribution of locally relevant digital content and offers seed funding for local enterprises.

A number of regulatory steps have also supported ICT development in Kenya (Schumann and Kende 2013). In 2008, the government established a unified licensing regime which allowed any company to bid for a license with only a few requirements[5] and without restrictions on the number of operators allowed to build and operate ICT infrastructure. Other measures included investments in submarine and terrestrial fiber optic cables, the removal of a value-added tax for mobile handsets, support for the development of the internet exchange point in Nairobi, sharing of the state-owned electricity company's infrastructure and reduction in the cost of calling between different mobile networks. These measures have played an important role in attracting private sector investment, increasing competition, improving the quality of the network and reducing the cost of mobile access.

In an effort to further strengthen the sector, the government is developing Konza Technology City near Nairobi, which is being marketed as 'Africa's Silicon Valley'. Konza City is an integral part of the government's National ICT Master Plan 'Connected Kenya 2017', which was launched in February 2013 with the overall goal of becoming Africa's most globally respected knowledge economy by 2017 (Kenya ICT Board 2012). Specifically, the plan aims at developing 500 new ICT companies, 20 global innovations and 50,000 jobs. The government also adopted a National Broadband Strategy to establish faster and more reliable broadband connections around the country (Okutoyi 2012).

M-Pesa

M-services developers have also benefited from the success of Safaricom's mobile banking service *M-Pesa*. Since its launch in 2007, *M-Pesa* had expanded to almost 16 million active customers with over 90,000 agent outlets across the country (Safaricom 2016). While other mobile operators have also started to offer m-payment services, M-Pesa continues to dominate the market, accounting for 77 % of mobile money customers (as of June 2015) (CA 2015).

Through its widespread adoption, *M-Pesa* has helped to prepare the ground for m-services in Kenya, familiarizing many Kenyans with the use of their mobile phone for non-call related services. For instance, *M-Pesa* has been credited for the

[5] I.e., to have a Kenyan-registered entity with permanent premises, provide evidence of tax compliance, and, if foreign-owned, divest 20 % of ownership to Kenyans within 3 years of receiving the license.

relatively widespread use of SMS in Kenya (Boyera 2012) where 89 % of mobile users are sending SMS compared to 50 % in South Africa, 26 % in Nigeria and 20 % in Ghana (World Bank 2012). *M-Pesa* (and other m-payment systems) also provides supporting services for other companies offering m-services that require monetary transactions. Moreover, the agent network can be used to market other technologies, such as the first Intel-powered smartphone which is being sold exclusively through Safaricom to take advantage of the widely available and highly frequented Safaricom outlets (Macharia 2013).

A Growing Customer Base

The customer base for mobile phone-enabled services is growing rapidly, not least driven by Kenya's young and increasingly educated population. Almost 40 % of the economically active population was estimated to be below the age of 30 in 2012 (ILO 2011). School enrollment rates have been improving. By 2009, 50 % of children in their age group were enrolled in secondary school, up from a third in 2000.[6] The youth are tech-savvy and interested, exemplified by the fact that Kenyans are the second most prolific tweeters in Africa after South Africa.[7] According to the Kenya Technology, Innovation & Startup Report 2012, "[n]ever before has the digital consciousness of the Kenyan people been as alive as it is today" (Afrinnovator 2012, p. 2). This trend is also reflected in the rapid expansion of small ICT sellers, repairers and service providers in Nairobi who are servicing the low-income market in particular (Foster 2012).

Access to mobile phones is relatively high and improving. The majority of the population is covered by mobile services (85 % in 2008/2009[8]) thanks to a growing network of fiber optic cables. 3G networks are available (though do not always perform well) and plans to roll out LTE are also in place. By December 2013, mobile phone subscription rates were 77 per 100 people, up from 0.41 per 100 in 2000.[9] In 2010, the number of mobile phone subscribers for the first time exceeded the number of people above the age of 15 (Fig. 9.2). These rates compare well to the regional average of 75 per 100 across Africa and 95 per 100 in developing countries in 2013.[10]

Subscription rates only provide a general indication of mobile phone access in a country. The GSMA believes unique subscription rates in Kenya to be considerably lower than total subscription rates, at around 37 % (Makau 2012). Nevertheless, access

[6] World Bank, data.worldbank.org. Accessed 25 Jan 2012.

[7] According to a survey carried out in the last quarter of 2011 (Portland Communications 2012).

[8] Waema et al. (2010).

[9] CCK statistics, ca.go.ke/index.php/statistics. Accessed 9 Sept 2014.

[10] ITU statistics, www.itu.int/en/ITU-D/Statistics. Accessed 9 Sept 2014.

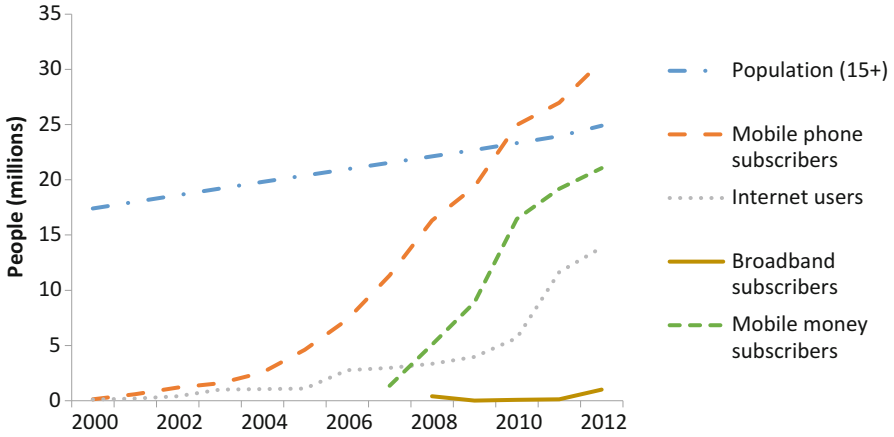

Fig. 9.2 Mobile phone, mobile money and internet penetration in Kenya. Note: The number of internet users was calculated by multiplying the share of the population using the internet (ITU) with the population (World Bank) (Data sources: ITU (mobile phone subscribers, share of population using the internet), World Bank (population), CBK (mobile money subscribers), accessed July 15, 2013)

to mobile phones is common in Kenya through the sharing of phones. One nationally representative survey found that 85 % of respondents used a mobile phone, although only 44 % owned a phone in 2009 (Wesolowski et al. 2012). Phone sharing was particularly prevalent among low income groups (Fig. 9.3) and in rural areas (even among higher income groups). Similarly, a survey of Kenyan farmers found that only around a third owned a mobile phone, but 84 % had used one (Okello et al. 2010).

The expanding mobile network also plays a critical role in facilitating access to the internet among Kenyan users. The vast majority of Kenyan internet subscribers (99 %) are accessing the web through mobile devices, including internet-enabled mobile phones and PCs with cellular modems (CA 2015). Internet usage began increasing significantly in 2010 (Fig. 9.2). While only around a third of Kenyans is estimated to use the internet, this share is almost three times higher than the African average (12 % in 2012) and one of the highest on the continent.[11] Internet uptake is particularly high by Sub-Saharan African standards if seen as a function of GDP, in part due to the low cost of internet compared to other countries in the region (Schumann and Kende 2013). Average download speeds from a local server are also considerably higher than in most Sub-Saharan African countries, with the exception of Rwanda and Ghana (in 2012) (ibid).

[11] ITU statistics, www.itu.int/en/ITU-D/Statistics. Accessed 15 July 2013.

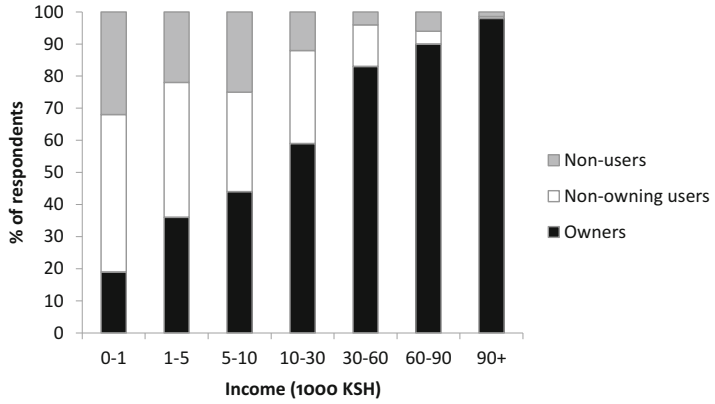

Fig. 9.3 Phone ownership and usage by income groups in Kenya (Source: Compiled by the author using data from Wesolowski et al. (2012))

. . . *and Challenges*

While Kenya's ICT ecosystem has come a long way in recent years, it is still maturing, and Kenyan entrepreneurs continue to face significant hurdles. Many start-ups struggle to move from initial idea to scale. The companies often do not involve enough marketing and business people due to a lack of funding, although these skills are particularly important as they seek to scale their businesses (Kieti 2012). Also, more mentorship and work experience in larger companies is needed to close the gap between a junior developer and the more senior established developers. Foreign companies could help start-ups graduate from small to medium-sized companies by outsourcing certain activities to local developers. However, lack of awareness of the local talent pool and difficulties in weeding out the good from the bad start-ups have so far prevented them from doing so.

There are also shortcomings in available training opportunities. While some universities are recognizing the importance of integrating ICTs into their curricula, there are no interdisciplinary courses that focus on building both sectoral expertise and practical software development skills. Moreover, university curricula are often insufficiently adapted to industry requirements. As Michael Macharia, CEO of Seven Seas Technologies in Kenya, observes, "there' s an urgent need to incorporate industry needs in university curricula across all our universities to ensure industry relevance" (cited in Mutua 2012).

A better understanding of the needs of the customers and the context in which the m-service is provided would also be beneficial. Companies rarely involve sectoral experts, such as health, education or agricultural specialists, to develop a product that meets specific needs. Also, too many m-services are developed with limited background research or interaction with potential customers. At times, developers appear too focused on building the next big idea or on pitching the idea at one of the numerous competitions. Much hope is pinned on earning big

money by developing apps and selling them through the app stores, even though the revenue-generating potential is rather uncertain.[12] As a result, m-services risk turning into technology solutions, rather than solutions that address a particular demand. This problem is not restricted to Kenyan developers, however. As Ken Banks, the founder of *FrontlineSMS*, points out, in the ICT4D (ICT for development) community, "Mobile is still largely seen as a solution, not a tool" (Banks 2013).

Access, in particular to mid-level funding that would allow start-ups to scale, continues to pose a challenge. "There remains a gaping hole in the market where venture capital activity should be [...] there are few venture capital funds dedicated to funding [IT and mobile] entrepreneurs in East Africa" (Deloitte 2012, p. 19). Some investors are reluctant to engage with Kenyan start-ups because of limited exit opportunities, such as selling their interests to a larger investor. Investors are also often not aware of investment opportunities. In particular, Kenyan investors have so far not shown much interest in local tech start-ups, preferring safer and often bigger investments that bring high returns.[13] At the same time, "many of the nascent entrepreneurs are probably not yet ready for venture capital" (ibid). Indeed, start-ups sometimes hesitate to seek investors because they do not want to give up control of the company too early.[14]

Moreover, while the IT infrastructure is fairly advanced by regional standards, it still faces problems. Overall, the share of the population using the internet is still low at less than a third in 2012 (Fig. 9.2) and only 11 % of internet subscribers had access to broadband (CCK 2013). Access to the mobile network and internet has at times been disrupted by damage to the sea cables (Okuttah 2012), and power cuts continue even in Nairobi. In addition, while the liberalization of the licensing regime has helped to attract investors, critics complain that it has encouraged higher investments in profitable areas, such as the deployment of multiple fiber optic cables in wealthy neighborhoods (Schumann and Kende 2013).

Rural areas continue to lag far behind in terms of the reach and quality of networks and related services. The cost of supplying telecommunication services to as yet underserved areas has been estimated at KSh74 billion (ca. $825 million) (Mumo 2013). The government's Universal Service Fund, which aims to collect a share of industry revenues to finance the expansion of mobile services, has been slow to get off the ground and is expected to fall short of the KSH one billion target in its first year 2013/2014 (ibid). The main challenges include high operational costs due to limited access to electricity, roads and infrastructure security, low population densities and high license and spectrum fees coupled with unclear

[12] A survey of over 1500 developers from around the world found that around a third cannot rely on apps as their only source of income, even if they sell several apps. Only 14 % will earn between $500 and $1000 and 13 % between $1001 and $5000 per app per month, while 25 % will not generate any income at all (VisionMobile 2012).

[13] Paul Kukubo, Chief Executive Officer, Kenya ICT Board @ Pivot East, 5 June 2012.

[14] Benjamin Matranga, Investment Officer, Soros Economic Development Fund @ Pivot East, 5 June 2012.

spectrum policies in these areas (Apoyo Consultoria 2011). In addition to network availability, download speeds also differ considerably within the country and will continue to do so even with the government's new broadband strategy (Okutoyi 2012).

M-Services for Kenyan Farmers

Kenya's agriculture sector is dominated by semi-subsistence, low-input and low-productivity farmers (Jayne et al. 2003). Agricultural holdings tend to be small at 2.4 acres on average (KNBS 2006).[15] Maize is the most widely grown crop in Kenya. The staple food is produced by 90 % of rural households and accounts for over 20 % of agricultural production (Bernard et al. 2010). Almost two thirds of maize production is generated by small-scale farmers (ibid). The second most widely grown crop is beans. Other important crops (i.e., with a harvested area of more than 100,000 ha in 2011–2013) include sorghum, tea, cow peas, coffee, wheat, pigeon peas, potatoes and millet.[16] Sugarcane is the main crop in terms of production volume, followed by maize, potatoes and bananas.

Various m-services are already offered to Kenyan farmers (see Table 9.1, excluding financial services). In most cases, assessing the reach and impacts of these services is difficult in the absence of publicly available data on users and impact assessments. Most of the services are offered by the private sector, including Kenyan companies (*M-Farm*, *KACE*, *mFarmer*, *kuza doctor*, *Agrimanagr*, *iCow*, radio stations), at times in collaboration with international companies (*M-Kilimo*, *ACRE*). Only a few services are led by government departments (*National Farmers' Information Service*, *Maize Variety SMS Service*) or international organizations (*Sokopepe*, *E-Farming*, index-based livestock insurance), and these are often also implemented in partnership with the private sector.

Agricultural m-services can be grouped into four categories: information and learning, financial services, access to agricultural inputs, and access to output markets. Most of the Kenyan services focus on information provision. Several deliver production-related information for crops (*ArifuMkulima*, *Sokopepe*, *kuza doctor*, *M-Kilimo*, *NAFIS*, *E-Farming*, *Maize Variety SMS Service*) or livestock (*iCow*) via SMS, phone calls and/or websites. Several radio stations also offer interactive programs to which farmers can send questions by SMS to the radio station which are then answered on air, in some cases using the software *FrontlineSMS* to manage the incoming SMS traffic. Several services also provide information on crop prices (see below and Box 9.1). The impact of these services

[15] "An agricultural holding is defined as all the land operated by a household for crop farming activities. [. . .] A holding may comprise one or more parcels." (KNBS 2006, p. 159).

[16] Data on production area and volumes: FAOStat, faostat.fao.org. Accessed 2 July 2015.

Table 9.1 Examples of m-services offered to Kenyan farmers (as of June 2013)

M-Farm mfarm.co.ke	Daily crop price information, selling of produce, purchasing of inputs (on hold), start date: October 2010
Kenya Agricultural Commodity Exchange www.kacekenya.co.ke	Weekly crop price information, *Soko Hewani* to sell produce through radio auctions, start date: 1997 (company)
SokoPepe www.sokopepe.co.ke	Agricultural information (e.g., climate changes, product prices, services for farmers, agricultural methods), selling of produce, start date: October 2010
SokoShambani www.mfarmerkenya.org	Mobile trading platform to link potato farmers and restaurants
ArifuMkulima www.mfarmerkenya.org	Agricultural information (e.g., weather, diseases, calendar alerts, farm inputs, financial advice, agrovets)
kuza Doctor www.backpackfarm.com	Agricultural production information for 10 crops (20 crops planned) in English & Swahili (Luganda planned), start date: August 2011
M-Kilimo www.m-kilimo.com	Agricultural information (e.g., land preparation, planting, pest management, harvesting, post-harvest and marketing), date: 2009–2011
National Farmers' Information Service (NAFIS) www.nafis.go.ke	Agricultural information (e.g., crops, livestock, market prices on inputs and outputs, other info), start date: April 2008
E-Farming[a]	Agricultural information (e.g., soils, fertiliser application, agronomy, markets or pesticide use), start date: 2012
Maize Variety SMS Service www.kephis.org	Information on the most suitable maize variety to grow in the division
iCow www.icow.co.ke	Livestock production information (e.g., info about local services, record keeping, best practice, cow calendar) and virtual livestock market, start date: June 2011
FrontlnieSMS Radio radio.frontlinesms.com, www.organicfarmermagazine.org	e.g. The Organic Farmer, *Pur Mariek* (farm wisely) on Radio Nam Lolwe, agricultural information on the radio in response to farmers' questions
FarmerVoice Radio www.farmervoice.org	Agricultural information, start date: July 2009
ACRE (formerly Kilimo Salama) kilimosalama.wordpress.com	Insurance to protect crops against drought or flood, start date: 2009
Index-based livestock insurance livestockinsurance.wordpress.com	Insurance against drought-related livestock mortality, start date: January 2010
Agrimanagr www.virtualcity.co.ke	Supply chain management, start date: 2010
farmforce www.farmforce.com	Supply chain management, start date: 2012

[a]Okoth (2013)

Box 9.1: The Case of *M-Farm*

M-Farm was launched in October 2010 by a small Kenyan start-up company as an m-service targeted at smallholder farmers in Kenya. *M-Farm* provides wholesale market price information for 42 crops (legumes, fruits and tubers, horticulture, cereals and eggs) from five markets in Kenya (Eldoret, Kisumu, Kitale, Mombasa, Nairobi). Farmers can access the information by sending an SMS to a short code to access a searchable database. The information is also available through the website and two apps. In addition, *M-Farm* assists smallholder farmers in collectively selling their produce to large buyers through contracts, and connects buyers and sellers via an internet- and mobile phone-enabled platform.

Price information and marketing services can help increase agricultural productivity in a number of ways. Access to price and demand information can encourage agricultural technology adoption by reducing uncertainties about the expected profitability of a technology (Abadi Ghadim and Pannell 1999). In Kenya, many small-scale farmers rely on a limited number of middlemen or traders to receive price information, given that search costs for finding information elsewhere are often high (Eggleston et al. 2002). Without this information (along with other uncertainties), farmers may not produce the most profitable mixture of crops or use efficient technologies (Eggleston et al. 2002).

Access to market information and linkages could also increase the prices that farmers are able to obtain for their produce. Due to limited access to price information, price signals in many rural areas are often "faint or absent" (Eggleston et al. 2002, p. 5). As a result, farmers are unable to find the most lucrative market to sell their produce and transactions tend to become localised (Stigler 1961). Moreover, in the absence of selling options, farmers tend to establish long-term trading relationships with a few traders – a process also referred to as 'clientelisation' (Geertz 1978). The consequent lack of competition combined with information asymmetries between traders and farmers worsens their bargaining position to negotiate prices for their crops (Svensson and Yanagizawa 2009).

The case study showed that farmers are using the price information from *M-Farm* to plan production processes, i.e., when deciding what to grow, when to harvest and who to sell to. While most price enquiries are sent at the sales stage, farmers also request price information at earlier stages of production. However, information about demand is often seen as more important for decision-making than price information. The price information has also encouraged farmers to change their cropping patterns by expanding certain crops, but was less influential in encouraging them to introduce new crops.

(continued)

Box 9.1 (continued)

Evidence as to whether the price information had helped farmers negotiate better prices is inconclusive. While farmers felt that they had been able to obtain better prices, an analysis of sweet potato prices in Rachuonyo does not show marked changes since farmers started using *M-Farm* (although the data are too limited to draw strong conclusions). Rather than price increases, perceived income gains may be attributable to changes in cropping patterns and harvesting times. The price information does not seem to have induced farmers to change traders on a large scale.

The survey data also suggests that the radio offers a viable alternative to *M-Farm* in disseminating price information. A third of the farmers still obtains price information from the radio since they started using *M-Farm* (compared to 42 % before) which they regard as comparable to *M-Farm* in quality. The radio is seen as a good source of information, particularly in the early stages of production, while *M-Farm* becomes more important closer to the selling stage.

Source: Field research carried out by the author

has not been assessed in any detail. A small survey of *iCow* users found that 82 % of farmers were still using the service 7 months later (iCow 2010). 42 % of farmers thought their income had increased, with just over half attributing income increases to increased milk yield.

In terms of financial services, access to transmission services is common even in rural areas, owing to the widespread availability of mobile payment services, such as *M-Pesa*, *airtel Money*, or *Iko Pesa* by Orange. However, while m-payments are widely available, usage of the service among Kenyan farmers for agricultural purposes appears to be limited. A study carried out in three districts of Kenya found that although almost all respondents had heard about m-payments (mainly M-Pesa), just over half (52 %) had used the service (Kirui et al. 2010). Only 13 % of the money sent was used to pay for farming-related items, such as inputs (7 %) and farmworkers (6 %).

With regard to other financial services, including credit, savings and insurance, only a few m-services are on offer. Mobile payment providers have also recently started collaborating with local banks to provide other banking services. *Orange Money* (Telkom Kenya and Equity Bank) and *M-Swhari* (Safaricom, Commercial Bank of Africa and Vodafone), for instance, offer micro-loans and savings accounts (including interest) to their users. Two mobile phone-assisted insurance plans are available in Kenya, both of which insure farmers against extreme weather events that might affect livestock (index-based livestock insurance) or crops (*ACRE*).

None of the m-services reviewed here focus on input provision. *M-Farm* initially offered a service for collective sourcing of fertilizer, but put the service on hold due

to liquidity constraints among farmers. *NAFIS* and *ArifuMkulima* provide price information for inputs, but it is unclear to what extent this function is operational.

Finally, several types of m-services aim at facilitating access to output markets. A number of information services have been developed in recent years which disseminate price information to farmers via SMS (*M-Farm*, *Sokopepe*, *SokoShambani*), USSD (*KACE*) and websites. Kenyan farmers are also able to sell their produce through internet- and SMS-supported selling platforms (*Sokopepe* and *M-Farm*).

In addition, the Kenyan company Virtual City uses mobile phones as part of their supply chain management system (*Agrimanagr*), allowing clients to record and track produce from delivery to final destination. A review of *Agrimanagr*'s performance showed that the system had reduced the delay in payments to farmers to 31 days (an improvement of 89 days) due to a faster consolidation of reports, cut purchasing times from 3 min to 22 s, and increased the average produce weight per transaction by 9–13 % with the use of electronic weighing technologies (Virtual City 2009). In addition, the Syngenta Foundation has trialed its supply chain management system *Farmforce* in Kenya which uses mobile phones to track deliveries from smallholder farmers to buyers.

Mobile Technology Outlook

Many of the m-services currently available in developing countries (including Kenya) 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 et al. 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, however, adoption rates of these technologies have not lived up to expectations, 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 ICT 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 $4 billion (US) have been invested in new submarine cables, almost doubling the data capacities in just 2 years (Schumann and Kende 2013). By 2012, 40 % of the Sub-Saharan African population lived within 25 km of an operational fiber node following a roll-out of terrestrial fiber 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.

Diversity of Mobile Connected Devices

The diversity of devices for accessing mobile services has been increasing in recent years. While basic and feature phones are still most prevalent in the developing world, high demand for mobile internet and price declines are expected to drive smartphone adoption in the future. Tablets may also offer a viable alternative to PCs in developing countries, in particular, lower-cost tablets now being produced in emerging economies, such as India and China. The expansion of these devices will support the growth of cloud computing, which is changing the way that m-services are used on personal mobile devices. 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 et al. 2011). The mobile device then functions simply as an interface to access the service, which is run elsewhere, thus requiring less processing power than that required to run it on the device.

Many more and increasingly sophisticated agricultural 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 analyze 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.

Internet of Things

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 et al. 2010, 1). 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).

In agriculture, the IoT has 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 behavior in response to the gathered data. Uptake of these technologies in developing countries has, to date, been limited (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.

A few examples of existing (small-scale) applications in developing countries highlight the potential of these technologies. For instance, data collection applications for mobile phones, such as *EpiCollect*, *Magpi* and *ODKCollect*, employ geo-tagging (using the phone's GPS) to gather location-specific data. For example, Makerere University in Uganda is using ODK Collect to automatically diagnose and monitor the spread of cassava mosaic disease (Quinn et al. 2011). 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). IoT devices are also being deployed in supply chain management. 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.

Capitalizing on Big Networks

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. Mobile connected devices are already gathering large amounts of data, e.g., on the location of the caller or calling patterns. In addition to these incidentally collected data, the devices can also be valuable sources of specifically collected data, e.g., through data collection tools or obtained through various IoT technologies (e.g., sensors, images or GPS tracking devices). Cloud-based services will facilitate the storage and analysis of such data and mobile devices can then be used as channels to disseminate the analyzed data. In agriculture, data collection 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.

ICTs are also facilitating social networking and learning. Several initiatives have begun emerging in the agricultural sector which use ICTs to support social learning among farmers. In India, for instance, *Lifelong Learning for Farmers* offers learning modules as recorded audio content delivered to female livestock producers through mobile phones (World Bank 2011). Also in India, *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.[17] Another example is *Sauti ya wakulima* (The Voice of the Farmers)[18] in Tanzania which was initiated by a small group of farmers who share two smartphones to publish images and voice recordings about their farming practices on the internet.

Conclusions

Kenya has firmly established itself as the main ICT hub of East Africa and one of the leading ICT centers on the continent. While the sector is not without its challenges, it should also be born in mind that it is still early days for Kenya's technology scene. Start-ups need time to grow into full scale businesses and investors need time to build sufficient trust in the viability of the sector. To what extent this development will assist or even transform Kenya's agriculture sector is still an open question. While a number of m-services are already available to farmers, most are still in the pilot phase and their effectiveness and reach have not been assessed.

Moreover, most of the available m-services use simple delivery technologies. Current technology trends offer numerous opportunities to develop more sophisticated m-services for farmers. However, many of the new technological opportunities have not yet been realized in practice – neither in industrialized 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 and which are most relevant in the given context. M-service developers will also need to ensure that their services continue to cater to a broad range of users rather than focusing overly on technologies that may not be within the reach of less-resourced farmers.

It is also important to stress that m-services can only ever be part of a broader solution. Farmers in the developing world face a multitude of challenges, some of which can be addressed through m-services, but many others of which cannot. Therefore, m-service should be embedded in complementary support programs and infrastructure developments to tackle other production and marketing limitations. Such complementary measures do not necessarily need to be implemented by the m-service provider, but can be the responsibility of other actors, such as companies, non-governmental organizations or government departments.

[17] www.digitalgreen.org.

[18] sautiyawakulima.net.

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