Agricultural Innovation and Service Delivery through Mobile Phones

Analyses in Kenya

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Summary

Mobile phones have become the most ubiquitous telecommunication technology in developing countries. To take advantage of this trend, businesses, government agencies and non-governmental organisations are increasingly turning their attention to the delivery of services through mobile phones (m-services) in areas such as health, education, agriculture and entertainment. In the agriculture sector, information services are most common while m-payments, virtual markets and supply chain management systems are also expanding. The use of mobile phones in agricultural service delivery is still at an early stage, however, and most of the services have yet to reach scale and long-term financial sustainability.

The dissertation examines how m-services could facilitate the participation of farmers in agricultural innovation processes, including the development and adoption of agricultural technologies. Four types of services are identified: information and learning, financial services, access to inputs and access to output markets. Existing empirical evidence in this research area is still scarce. To date, most of the research has focused on mobile phones as such. Only a few studies have looked specifically at m-services and their findings are not clear-cut. Several of them highlight benefits for farmers, including improved management practices, higher productivity or higher prices, while others do not find positive impacts.

Kenya is widely seen as frontrunner in the development of m-services in Sub-Saharan Africa. The growth of the vibrant technology scene was facilitated by a number of factors, including improving network infrastructure, government regulations and a supportive innovation environment that offers access to innovation hubs, finance and human resources. The growing customer base provides a promising market for m-service developers and through the mobile payment service M-Pesa, many Kenyans are already familiar with the use of their mobile phone for non-call related activities. A range of m-services are available for Kenyan farmers. However, the reach and scale of these services is still limited despite the conducive environment and their impacts have not been assessed.

The dissertation presents the case study of M-Farm, an m-service that offers price information and marketing services to Kenyan farmers. It examines how the service has impacted farmers' decision to adopt agricultural technologies and their ability to generate income from their use. Farmers were very enthusiastic about the positive impact of M-Farm on production decisions and income, but the study finds little other evidence to support this positive perception. Other constraints, such as risk of crop losses, lack of insurance and limited finances, were generally seen as more significant obstacles. The study also shows that the radio provides a viable alternative to disseminating price information in the early stages of production, while M-Farm becomes more important closer to the selling stage.

Existing m-services in the developing world are barely scratching the surface of what is technology possible. The dissertation examines how current technology trends may impact m-service delivery to farmers in the future. Three trends are identified, i.e. the growing diversity of mobile connected devices to access m-services; the 'Internet of Things' which links objects and people through the network; and the increasing ubiquity of mobile networks and expanding user base. The dissertation presents two scenarios for the evolution of mobile technology trends (Status Quo and Big Leap) and assesses their implications for agricultural service delivery.

Zusammenfassung

Mobiletelefone haben sich als die am weitesten verbreitete Telekommunikationstechnologie in Entwicklungsländern etabliert. Unternehmen, Regierungsbehörden und Nichtregierungsorganisationen nutzen diesen Trend, indem sie zunehmend Dienstleistungen über Mobiltelefone (m-Dienste) anbieten. Im Agrarsektor werden Informationsdienste am häufigsten angeboten, aber auch m-Zahlungen, virtuelle Märkte und Lieferkettenmangement-Systeme nehmen stetig zu. Landwirtschaftliche m-Dienste sind allerdings noch in einem frühen Stadium und meist nicht finanziell tragfähig.

Die Dissertation untersucht, wie m-Dienste die Beteiligung der Bauern an landwirtschaftlichen Innovationsprozessen verbessern könnten. Zu diesem Zweck wurden vier Arten von Dienstleistungen identifiziert: Informationen und Bildung, Finanzdienstleistungen, Zugang zu Produktionsmitteln, und Zugang zu Märkten. Empirische Forschungsergebnisse gibt es auf diesem Gebiet bisher nur wenige und die Schlussfolgerungen sind nicht eindeutig. Einige Studien zeigen positive Auswirkungen für Bauern, einschließlich verbesserter Management-Praktiken, Produktivität und Preisen, aber andere finden keine Beweise, dass Bauern von der Nutzung der m-Dienste profitiert haben.

Kenia gilt als Vorreiter in der Entwicklung von m-Diensten in Subsahara Afrika. Die Technologieszene konnte sich dank einer Reihe von Faktoren entwickeln, einschließlich verbesserter Infrastruktur, staatlicher Regulierung und Zugang zu Innovationszentren, Finanzierung und personellen Ressourcen. Der wachsende Kundenstamm stellt einen vielversprechenden Markt für m-Dienste dar und durch die weite Verbreitung des mobilen Bezahlsystems M-Pesa sind viele Kenianer schon mit der Nutzung ihrer Mobiltelefone für andere Dienste als Telefonate vertraut. Einige landwirtschaftliche m-Dienste werden schon angeboten, aber deren Reichweite ist noch begrenzt und die Auswirkungen sind nicht belegt.

Die Dissertation präsentiert die Fallstudie von M-Farm, ein m-Dienst, der Preisinformationen und Marketing-Dienste für kenianische Bauern anbietet. Die Studie untersucht die Auswirkungen von M-Farm auf die Entscheidung von Bauern, landwirtschaftliche Technologien einzuführen und dadurch ihr Einkommen zu verbessern. Obwohl die Bauern enthusiastisch von den Vorteilen des Dienstes für die Produktionsplanung und Einkommensgewinnung berichten, konnte die Studie wenig andere Beweise für diese positive Einschätzung finden. Zusätzliche Einschränkungen, wie das Risiko von Ernteausfällen und begrenzte finanzielle Ressourcen, scheinen größere Hürden für die Nutzung von neuen Technologien darzustellen. Die Studie hat außerdem gezeigt, dass das Radio eine gute Alternative zur Verbreitung von Preisinformationen in den frühen Stadien der Produktion darstellt, während M-Farm vor allem in der Verkaufsphase wichtig wird.

Die Dissertation hat außerdem untersucht, wie aktuelle Technologietrends die Bereitstellung von m-Diensten in der Landwirtschaft in Zukunft beeinflussen könnten. Drei Trends werden analysiert: erstens die wachsende Diversität von mobilen Geräten, um m-Dienste zu nutzen; zweitens das 'Internet der Dinge', das Objekte und Menschen durch ein Netzwerk verbindet; und drittens die zunehmende Verbreitung von mobilen Netzwerken und eine wachsende Nutzerbasis. Die Dissertation stellt zwei Szenarien für die Entwicklung von Mobiltechnologien vor und analysiert deren Auswirkungen auf landwirtschaftliche m-Dienste.

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Abbreviations

ADS	Anglican Church of Kenya Development Services
CKW	Community Knowledge Worker
EAG	East African Growers
EASSy	East African Submarine Cable System
FGGD	Food Insecurity, Poverty and Environment Global GIS Database
GDP	Gross Domestic Product
GIS	Geographical Information System
GPS	Global Positioning System
HetNets	heterogeneous networks
ICT	information and communication technology
IDI	ICT Development Index
IoT	Internet of Things
IP	Internet Protocol
ITU	International Telecommunications Union
IVR	interactive voice response
IXP	internet exchange point
KSh	Kenyan Shilling
LION2	Lower Indian Ocean Network
M2M	machine-to-machine communication
MNO	mobile network operator
m-service	mobile phone-enabled service
NDVI	normalised differenced vegetation index
NGO	non-governmental organisation
NRI	Networked Readiness Index
PC	personal computer
PRAM-KSN	Poverty Reduction and Agricultural Management – Knowledge Sharing Network
RFID	radio-frequency identification
RML	Reuters Market Light
SMS	Short Message Service
TEAMS	The East African Marine System
USSD	Unstructured Supplementary Service Data
VRA	variable rate application
WAP	Wireless Application Protocol
WiBack	Wireless Backhaul Technology
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	wireless local area networks

1 Introduction

1.1 Context

Mobile phones have become the most ubiquitous telecommunication technology in developing countries where subscription rates have soared from 250 million in 2000 to almost 7 billion 13 years later.[1] This rapid expansion was made possible through falling handset prices and calling rates, the introduction of pre-paid mobile phone packages and the expansion of networks into rural areas. While users in Africa initially included mainly male, educated, young, wealthy and urban populations, the share of poor, elderly and rural individuals has also been increasing (Aker and Mbiti, 2010). In addition to growing subscriber rates, phone sharing with family, friends or phone shops is also widespread in many developing countries.

Looking at access statistics alone, however, gives us little insight into the developmental potential and impact of mobile phones. Rather, the starting point of the analysis needs to be to what extent people choose and are able to utilise their phones to improve their well-being. The capability approach put forward by Amartya Sen and further developed by other scholars has emerged as an important analytical framework in this regard. Sen regards people's freedom "to lead the kind of lives we have reason to value" (Sen, 1999, p. 285) as the primary means of development. As Robeyns (2005) elaborates, what is ultimately important is that people have the "effective opportunities [what Sen refers to as capabilities] to undertake the actions and activities that they want to engage in, and be whom they want to be" (p. 95).

Garnham (1997) was the first to make the link between communication and the capabilities approach. He stresses that it is not access to communication options that is crucial "but the distribution of social resources which make access usable" (p. 27). Several researchers have since followed suit (e.g. Alampay, 2006; Birdsall, 2011; Coeckelbergh, 2011; Gigler, 2004; Johnstone, 2007; Kleine, 2011; Madon, 2005; Smith et al., 2011; Zheng, 2009). Most would agree that information and communication technologies (ICTs) can contribute to enhancing human capabilities, e.g. by facilitating information exchange, communication, knowledge generation and networking. Sen himself points out that on the whole, mobile phones have been "a boon, rather than a curse, for societies" (Sen, 2010, p. 2). Indeed, ICTs can contribute to the expansion of human capabilities across a wide range of areas, such as health, education, livelihoods or entertainment. As Oosterlaken (2012) notes:

> ICTs might thus be seen as the ultimate embodiment of the ideal of the capability approach that we ought to promote a variety of capabilities and leave it up to empowered individuals which functionings to realize, depending on their idea about the good life. (pp. 12-13)

The specific linkages between ICTs and capability enhancement have not yet been well articulated, however, in part due to differences within the research community on how to select and operationalise relevant capabilities (Birdsall, 2011). Also, most researchers look

[1] ITU (International Telecommunications Union) statistics, www.itu.int/en/ITU-D/Statistics, accessed 1 September 2014

at ICTs in general rather than distinguishing between different technologies. One study which focuses specifically on mobile phones notes that they can serve as a means to altering users' capability sets by facilitating access to information and connectedness, including through social, economic and governance networks (Smith et al., 2011). The functionings that people can then achieve by using mobile phones are somewhat secondary "because it is (ideally) the result of an individual's personal choice according to his or her value system" (Zheng, 2007, p. 8). To what extent they are able to do so will depend on a range of factors related to the users and the context.

Services that are offered through mobile phones (referred to as 'm-services' in this dissertation) could increase the utility of the phone to enhance human capabilities. M-services can expand existing functionalities, for instance through information services that allow users to access a wider range of information than would be available otherwise. Similarly, mobile phone-enabled platforms can facilitate the use of the phone for networking purposes. At the same time, m-services can offer additional functionalities to those available through the phone itself, for instance by allowing users to make financial transactions using m-payments. Conceptual and empirical research into these linkages is still missing, however.

M-services have been flourishing in recent years as companies are starting to see the business opportunities in this area. The German software company SAP, for instance, is piloting supply chain management systems for small producers in Ghana, Nokia and Reuters Thomson are delivering information services to mobile phones users in India, and Google is linking buyers and sellers through mobile and internet-based platforms in Uganda. In addition to large international companies, smaller local businesses are also starting to deliver services in sectors such as health, education and agriculture, supported by emerging innovation hubs in several developing countries.

A review of m-services conducted in September 2012 analysed 800 live initiatives in the developing world (Hatt et al., 2013). Most of the growth has taken place since 2009. Health-related services account for the largest share by far, notably in Asia and Africa. The less widely available mobile money applications are particularly prevalent in Africa while m-learning tools are mainly offered in Asia. Around half of the m-services generate revenue by selling a product or service to consumers while a similar share is donor-funded (mainly in m-health). At the time of the review, many of the m-services were still struggling to reach scale (with the exception of the mobile money sector). Today, the number of m-services is likely to be much larger given the rapid expansion of start-ups and related services.

Mobile phones and m-services could offer particular opportunities for the rural poor who in the absence of landlines and computers often lack alternative means of telecommunication and internet access. von Braun and Torero (2006) predict that telephony will be "the ICT that will have the greatest penetration and impact when it comes to poor people" (p. 3). They argue that mobile phones could help to reduce physical and social marginalization of poor regions and people by facilitating communication that is not restricted by distance, volume, medium and time, thereby overcoming barriers of space and social standing. However connectivity alone (e.g. signal coverage) is not sufficient to ensure that poor regions can benefit from mobile phones, they stress. Equally important are the ability to pay for the ICT-based services, the skills to use the technologies effectively and the accessibility and usefulness of the mobile content and functions.

In particular the application of m-services in the agriculture sector has the potential to reach and assist the rural poor. In many developing countries, the sector is characterised by a large number of smallholder, often subsistence farmers with low productivity and limited use of agricultural technologies. As will be elaborated below, m-services may offer opportunities to address some of these constraints. However, to date, agriculture-related m-services constitute only a small share of m-services (Hatt et al., 2013). Challenges include price sensitivity among rural consumers, difficulties to scale, lack of content providers and low levels of literacy (ibid). On a positive note, the large untapped rural market also offers significant business opportunities for service providers.

Several studies have sought to outline the utility of mobile phones and m-services to support agricultural production and promote rural development (Aker, 2011; Donner, 2009; Qiang et al., 2011; Vodafone Group and Accenture, 2011; World Bank, 2011) (summarised in Table 1-1). Better access to information, markets and financial services are among the most commonly cited uses of mobile phones in this sector. Several of the studies also see great potential for employing mobile phones in the delivery of extension and other public services (Aker, 2011; Donner, 2009; Qiang et al., 2011; World Bank, 2011) and in supply chain management (Aker, 2011; Qiang et al., 2011; Vodafone Group and Accenture, 2011; World Bank, 2011).

Table 1-1: Studies on the utility of mobile phones in agricultural production

Study	Mobile phones in agriculture
Qiang et al. (2011)	• Accessing markets, disease and climate information • Accessing to extension services • Improving market links and distribution networks • Accessing finance, including credit, insurance and payment methods
Aker (2011)	• Accessing information from private sources or through agricultural extension services • Better management of input and output supply chains • Facilitating the delivery of other services • Increasing the accountability of extension services • Increasing linkages with research systems
Vodafone Group & Accenture (2011)	• Accessing financial services • Obtaining agricultural information • Improving data visibility for supply chain efficiency • Enhancing access to markets
World Bank (2011)	• Enhancing farm-level productivity • Accessing markets and value chains • Improving public services delivery
Donner (2009)	• Mediated agricultural extension • Market information systems • Virtual markets • Financial services • Direct livelihood support

These studies tend to focus on different kinds of m-services that are meant to serve a broad goal, such as agricultural and rural development (Qiang et al., 2011), efficiency and sustainability in the supply chain (Vodafone Group and Accenture, 2011) or delivery of extension services to support the use of improved agricultural technologies (Aker, 2011). This dissertation builds on existing studies by exploring how m-services can be used to engage farmers in agricultural innovation processes and thereby increase their well-being, and outlines a conceptual framework in this regard. An m-service is understood to include the provision of *mobile content* (i.e. electronic media that are accessed through mobile phones such as images, audio recordings, graphics, videos or text) or *functions* offered through the mobile phones (such as banking facilities, marketplaces or social networking platforms).

The dissertation also provides a systematic analysis of existing empirical evidence to substantiate the conceptual linkages identified. To the author's knowledge, no comprehensive literature review examining evidence on the impacts of mobile phones on agricultural technology innovation – or indeed on farmers more generally – has so far been published. Existing literature reviews related to mobile phones have focused on micro- and small enterprises (Donner and Escobari, 2010), financial services (Duncombe and Boateng, 2009) and m-commerce (Ngai and Gunasekaran, 2007), while the above-mentioned studies tend to rely on case studies and selected empirical studies. The dissertation further adds to the literature by assessing how mobile phones and m-services could support in particular the poorest and marginalised farmers.

The literature review shows that existing empirical evidence is still insufficient to draw strong conclusions regarding the role of m-services in facilitating agricultural innovation. To help address this gap, the dissertation includes a case study of the m-service *M-Farm*. The service is run by a small Kenyan start-up company and offers price information to Kenyan farmers via mobile phones and links them to potential buyers. The aim of the study is not only to understand the impacts of the service, but also to look at the potential for local start-up companies such as *M-Farm* to develop and market services to smallholder farmers, including the role of the companies themselves as well as the environment in which they are operating.

Kenya was chosen as the study country for this research because of its role as an emerging ICT leader 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 such as Nokia and Google which are setting up offices in Nairobi, local start-ups have also been expanding rapidly. Kenyan entrepreneurs have greatly benefited from the growth of the local innovation environment in recent years. At the same time, poverty levels are still high, in particular in rural areas.[2] Agricultural production is dominated by small-scale, low-input farming, offering significant opportunities to promote rural development through agricultural innovation. The widespread adoption of the mobile payment service *M-Pesa* has helped to prepare the ground for m-services in rural areas since many farmers are already familiar with the use of their mobile phone for non-call related services.

It is also important to note that many m-services in the developing world remain well below the technological potential. For now much of the focus has been on offering services through SMS (Short Message Service) and voice-based interfaces to cater to users with low-tech mobile phones. In the future, new technology trends could offer much more diverse and sophisticated applications. The growth of cloud computing, for instance, allows for the storage of large amounts of software and data remotely so that mobile devices merely serve as an interface without requiring complex computing or storage capacities. Another example is the so-called 'Internet of Things' where sensors are linked through cellular and cable

[2] The share of people living below the national poverty line in Kenya's rural areas was 49% and 46% in Kenya as a whole (in 2005). World Bank, data.worldbank.org/country/kenya, accessed 10 January 2013.

networks, such as crop insurance schemes that use data from weather stations to trigger pay-outs via mobile phones. While businesses in high-income countries are increasingly capitalising on these trends, related applications are still at an early stage in the developing world and their utility for lower-income farmers has not been systematically assessed.

1.2 Research questions

Against the background of knowledge gaps outlined above, the dissertation aims to address the following overarching question: How could mobile-phone enabled services enhance famers' capabilities to engage in agricultural innovation processes? To answer the main research question, the following sub-questions are addressed:

- Why are some m-services succeeding in enhancing farmers' participation in agricultural innovation processes?
- To what extent are the different strata of the poor able to benefit from the m-services?
- What is the potential of new mobile technology trends to extend the functionalities and utility of m-services?

The remaining dissertation is divided into four chapters:

- **Chapter 2** outlines how m-services could potentially facilitate the participation of smallholder farmers in agricultural innovation processes. The chapter goes on to review available empirical evidence to assess whether these conceptual linkages have been shown to work in practice and identifies existing research gaps. The chapter also examines to what extent the poorest and marginalised farmers are likely to benefit from mobile phones and m-services.
- **Chapter 3** discusses current and future trends in m-service delivery globally and in Kenya. To this end, the chapter reviews recent technological trends related to mobile phones and m-services, outlines two scenarios on the possible evolution of these trends in the future and assesses how these may impact on m-service delivery to farmers in developing countries. It also provides an overview of mobile technology trends in Kenya, including the ICT ecosystem for local entrepreneurs and the m-services that are offered to Kenyan farmers.
- **Chapter 4** presents the results of an empirical study of the Kenyan price information and marketing service *M-Farm*, based on interviews, focus group discussions and a survey of *M-Farm* users in two districts of Kenya. In addition to analysing the impacts of the service, the study also examines the history of the company providing the service, the factors that have contributed to its growth, and the challenges and opportunities for scaling up the service.
- **Chapter 5** summarises the key findings of the research and identifies areas of further work.

2 The role of M-services in Agricultural Innovation: A Review of Conceptual Linkages and Evidence

Drawing on selected literature related to development theory, innovation systems, agricultural technology adoption and information economics, this chapter describes a conceptual framework on the potential role of m-services in enhancing farmers' capabilities to engage in agricultural innovation systems and thereby increase their well-being. Four types of services are identified – information and learning, financial services, access to inputs and access to output markets – which could support farmers' participation in the development and adoption of agricultural technologies. The chapter goes on to review empirical studies related to the conceptual linkages to assess the extent to which these have been shown to play out in practice and where further research is needed. The final section examines the potential of m-services to engage marginalised and poor farmers more specifically.

2.1 Conceptual Framework

The conceptual framework builds on Amartya Sen's capability approach (e.g. Sen, 1993, 1999) as the underlying theory of development and its application to ICTs by Dorothea Kleine (2013, 2011). Sen argues that rather than defining development as a particular outcome, the emphasis should be on what people are able to do or be, or in Sen's terminology their 'capabilities' which he describes as "a person's ability to do valuable acts or reach valuable states of being" (Sen, 1993, p. 30). Development can be promoted by removing obstacles in people's lives so that they have more freedom to live the kind of life that they have reason to value. The resulting 'beings and doings' (or functionings) together constitute what makes life valuable. The quality of life should then be assessed "in terms of the capability to achieve valuable functionings" (Sen, 1993, p. 31).

People's capabilities are shaped by various factors related to the person and the context they find themselves in. Kleine (2013) distinguishes between individual agency-based capability inputs (or resources) and structure-based capability inputs. She identifies eleven types of resources that individuals can convert into capabilities: material, financial, natural, geographical, psychological, cultural, social, and educational resources; time; health; and information. Structural factors include formal and information institutions, such as laws, social norms and customs. Thus, "individuals use their resource-based agency to negotiate the social structure, constantly making choices generally aimed at their notion of what kind of life they want to live" (Kleine, 2011, p. 124).

Goods and services can also be a means to achieving functionings which is of particular relevance to this dissertation. A mobile phone, for instance, has no value in itself. Rather, it offers a range of opportunities, such as accessing information or communicating with others, which a person can then choose to realise. Whether a person is able to do so again depends on various conversion factors, including personal (e.g. literacy or income) and structural (e.g. gender attitudes in society or availability of a mobile phone network). Services that are provided through mobile phones can affect the utility of the phone to achieve certain functionings by altering existing opportunities (e.g. information provision, communication or networking) or adding new ones (e.g. financial transactions).

The functionalities and design of the m-service will shape its potential to enhance human capabilities. Kleine (2011) notes that technologies can be placed on a determinism continuum, depending on the extent to which they prescribe a certain usage and thereby affect people's abilities to make choices. For instance, each smartphone uses a particular operating system (e.g. Android or Apple's iOS) which will influence the apps and services that can be accessed (see also Section 3.1.2). At the same time, the design of m-services can be impacted by underlying ideologies. For example, m-services offering information on farming practices will generally be influenced by the type of agriculture the service providers envisage (e.g. organic or input-intensive agriculture).

The dissertation explores the linkages between capabilities and m-services with regard to farmers' ability to innovate and thereby improve their well-being. Following Rogers (2003), an innovation (or new technology) is defined as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p. 12). The focus here is on agricultural technologies which include both physical objects such as seeds, fertiliser or irrigation, as well as new farming methods. Innovation can help farmers e.g. to improve agricultural productivity, competitiveness or the environmental sustainability of production. Through these channels, innovation can provide a means to achieving certain functionings, such as being well-nourished, protecting the natural environment or earning sufficient income to finance education.

Agricultural technology innovation takes place within innovation systems which are here defined as "a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance" (World Bank, 2006, pp. vi–vii). The innovation system approach emerged in the mid-1980s, building on the work of Friedrich List on 'The National System of Political Economy' in the mid-1800s (List, 1841) and Schumpeter who highlights the interplay of society and innovation as a driver of technological change (Schumpeter, 1939). In agriculture, systems-oriented approaches to innovation began attracting attention in the 1990s (World Bank, 2012a). Previously, a more linear approach had dominated research planning where knowledge generation was seen to be the primary responsibility of research organisations which then transfer technologies to farmers via extension programs (Spielman, 2005).

The innovation systems approach takes into account the complexity of the research process, including the motives and behaviours of different public and private agents, the linkages between these agents and the institutions that govern their interactions and the resulting innovation processes (Spielman, 2005). Importantly, the approach recognises the role of farmers as innovators along with other agents, such as private companies, public institutions and other non-state actors (see e.g. Biggs & Clay, 1981; A. Hall & Clark, 1995). It also stresses that innovation systems are dynamic and evolutionary. Thus technological, institutional and environmental change will influence innovation processes and the role of different agents within the system. Among these drivers, this dissertation focuses on technological change, including agricultural technologies (as the output of the innovation process) and mobile technologies (as facilitators of the innovation process).

Figure 2-1 describes a conceptual framework outlining the opportunities of using m-services to enhance farmers' capabilities to engage in agricultural innovation systems. The conceptual framework draws together insights from studies related to mobiles phones in agriculture, research into innovation systems and development more generally and a review of m-services that are already offered to farmers in developing countries.

The innovation process is broadly divided into two interlinked components, i.e. the development of innovations and the adoption and use of innovations (Sunding and Zilberman, 2001). The development of new technologies will require

- an understanding of the **demand** for agricultural technologies, including the needs of farmers and markets, and
- **research & development**, including the development of prototypes, testing and adjusting.

Technology adoption will involve

- the **decision to use** the agricultural technologies based on an assessment of its suitability for the farming system, expected profitability and potential risks,
- the ability to **access** the agricultural technologies, including to physically obtain and finance them,
- the ability to **use** agricultural technologies, including the knowledge of how to use them, necessary resources (e.g. sufficient labour, water or supplementary inputs) and the ability to manage any associated risk , and
- the ability to **generate income**, including to profitably sell surplus produce and save and reinvest the resulting returns.

To what extent farmers are able to engage at the different stages of the innovation process will be influenced by their capability set which in turn is shaped by personal and contextual factors. With regard to personal factors (or agency-based capability inputs), the conceptual framework uses the resources identified by Kleine. M-services can change a person's resource portfolio (e.g. increase the information available or widen their access to social networks). At the same time, the resource portfolio will influence to what extent farmers can make use of m-services (e.g. literacy or income). This dynamic process is also affected by the development outcomes of farmers' participation in innovation processes (e.g. where innovation leads to higher incomes which is invested in education and thereby allows households to make use of more sophisticated m-services).

The conceptual framework includes four categories of m-services which can be used to enhance farmers' capability set and thereby opportunities to engage in innovation processes:

1. information and learning e.g. mobile surveys, social networking and learning, farming information and training
2. agricultural inputs, e.g. input and labour markets
3. financial services, e.g. transmission services, loans, savings and insurance
4. output markets e.g. marketing information, virtual markets and supply chain management

The design and functions of m-services are subject to continuous technological change in the mobile sector which in turn affects the services' potential to change farmers' resource portfolio. In this context, technological change includes advances in hardware (i.e. the capabilities of mobile phones and networks) and software (i.e. the functionality of m-services).

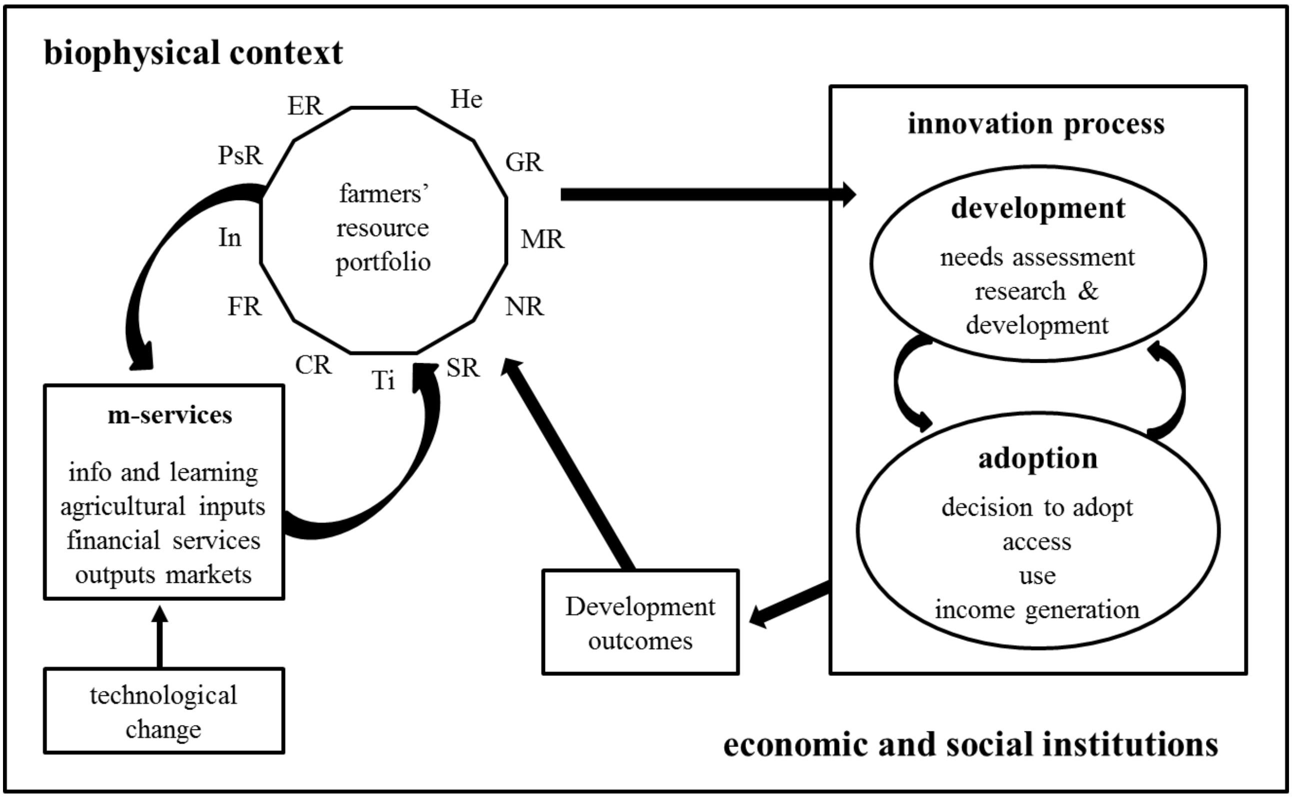
The resource portfolio, the ability to turn personal resources into functionings and the innovation process as a whole are also influenced by the biophysical context in which the farmers operate and the prevailing social and economic institutions. Institutions are defined as "the rules of the game in a society or, more formally, […] the humanly devised constraints that shape human interaction. In consequence, they structure incentives in human exchange, whether political, social, or economic." (North, 1990, p. 3). Institutions that are relevant in the context of innovation systems include "laws, regulations, conventions, traditions, routines, and norms of society that determine how different agents interact with and learn from each other, and how they produce, disseminate, and utilize knowledge" (Spielman, 2005, p. 15).

Among the institutions, government regulations can play an important role in stimulating the development and uptake of m-services. Relevant regulatory areas include the taxation regime for customer and corporate taxes, licensing of mobile operators, access pricing (e.g. for infrastructure sharing or charges applied to network interconnections), radio spectrum management and co-financing (Blackman and Srivastava, 2011; Katz et al., 2010). Regulatory changes in these areas will impact the level of competition between mobile operators and m-service providers, investments in infrastructure and private m-services developers, and the cost and quality of mobile services. Section 3.2.1 elaborates on the role of regulations in the Kenyan context.

The remaining section assesses in more detail how m-services could help farmers to actively participate in innovation systems, using the four categories of services outlined above. A box at the end of each sub-section features examples of existing m-services[3] while Chapter 3 examines how current technology trends are likely to lead to new and improved m-services in the future. The section also explores the dynamic nature of innovation systems to assess how technological change in the mobile sector impacts the utility of m-services.

[3] Web links to the m-services cited in this dissertation are provided in the References.

Figure 2-1: Engaging farmers in agricultural innovation systems through m-services



ER = educational resources	CR = cultural resources	MR = material resources
PsR = psychological resources	Ti = Time	GR = geographical resources
In = Information	SR = social resources	He = health
FR = financial resources	NR = natural resources	

Source: compiled by the author; resource portfolio based on Kleine (2013)

2.1.1 Information and learning

In many parts of the developing world, the most common way of obtaining information remains personal travel which is costly both in terms of time and money (Aker & Mbiti 2010). Information may also be asymmetrically distributed, i.e. some market participants have access to the information while others do not, or information is simply not available. As a result, "individuals do not acquire perfect information, and hence their behavior may differ markedly from what it would have been had they had perfect information" (Stiglitz, 1988, p. 100). Possible impacts of imperfect information in the agriculture sector include low(er) productivity e.g. because farmers are not aware of the most productive farming methods, imperfect distribution of risk in the economy, price dispersion, inefficient markets or a failure for markets to emerge at all (Bedi, 1999; Stiglitz, 2007, 1988).

Mobile phones can play a role in improving access to information "due to their ability to support the decoupling of information from its physical repository" (Bedi, 1999, p. 5). Thereby, they not only reduce the cost of searching for and transmitting information, but also allow for more regular, reliable and timely access to information (Bedi, 1999). Mobiles could also overcome the limitations of other information dissemination channels, given that they are more versatile and interactive than TV and radio, cheaper and more accessible than the internet, and require lower levels of literacy and are less concentrated in urban areas than newspapers (Aker 2011; Jensen 2010).

M-services can be used to transmit different types of information, including information on farmers' needs, information used in farming (e.g. on the performance of technologies, farming practices, the weather or disease outbreaks) and information used in marketing (e.g. information on prices, demand, buyers or sellers). This section focuses on the first two types, while Section 4.1 discusses the role of marketing information in more detail.

Technology development

To ensure that innovations respond to the needs of the farmers, it is important to understand constraints on increasing profitability and which of these constraints could be addressed through technological solutions, such as access to improved seeds, fertiliser or farming methods. Moreover, the need for complementary measures, such as better access to markets or finance, will also need to be assessed. This requires repeated interaction between farmers and researchers, but also other agents involved in the agriculture sector, such as national and local governments, traders or private companies.

Farmers can also be more actively engaged in the research process (Biggs and Clay, 1981; Hall and Clark, 1995). They can test new technologies developed within the formal research system to study how the technologies are performing in the field under different conditions. Farmers could also share experiences with researchers or other farmers gained through their own experimentation with agricultural technologies independent of the formal system.

Mobile phone-based survey applications can be used to gather data on farmers' needs and to monitor formal field trials or informal experimentation. Such surveys can be completed by enumerators surveying the farmers, or by the farmers themselves. Using m-surveys can facilitate data entry by uploading the gathered data directly into a database, reduce mistakes resulting from transcription, and increase the reach and frequency of surveys which may not be cost-effective to undertake through personal visits. M-services can also facilitate information exchange and networking by strengthening existing linkages between agents in the innovation system and helping to bring new actors into the system.

Technology adoption

Different types of information can play a role in farmers' decision to adopt new technologies. Farmers will require the necessary information to assess the suitability of the technology for their farming system and to understand (and manage) the potential risks associated with the use of the technology.[4] Moreover, farmers may be uncertain about the profitability of the new technology or differences in economic returns between new and old technologies due to insufficient knowledge about yields, needed inputs, or expected market prices and demand (Abadi Ghadim & Pannell 1999). Unexpected weather conditions, climatic shocks or disease outbreaks also increase uncertainty and risk, in particular among subsistence farmers who are dependent on rainfall (Kaliba et al., 2000). Farmers also require

[4] See Marra et al. (2003) for a review of theoretical and empirical literature on the role of risk and uncertainty in technology adoption decisions.

the necessary knowledge and information to use technologies, generate economic returns and manage any associated risks.

Information from external sources, such as agricultural extension agents, m-services, radio, TV or newspapers, can play a central role in the assessment of the suitability and risk of a technology and its effective use. A study of maize adoption in Tanzania, for instance, shows that high intensity of extension services was one of the major factors positively influencing the adoption of improved seeds (Kaliba et al., 2000). Advice on farming practices is one of the most widely available m-service in agriculture, often as a complement to existing extension services. M-services offering information related to the production environment (e.g. on weather or crop diseases) are also available to assist farmers in better understanding and managing risks. M-services providing information on market prices and link farmers to buyers are helping them to assess and realise the economic potential of new technologies (see also Sections 2.1.4 and 4.1).

Alternatively, farmers may be encouraged to adopt new technology by learning from other farmers who are already using the new technology. Foster and Rosenzweig (1995) find that farmers with experienced neighbours were more likely to devote more land to new technologies. Vicinity alone may not be sufficient, however. Rather, farmers appear to learn through more limited social networks that are not based only on geographic proximity (Conley and Udry, 2001). M-services can be used to facilitate social learning by offering platforms to exchange information and experiences. While mobile phones are increasingly used to facilitate social networking in developing countries through services such as Facebook and Mxit (see also Section 3.1.2), they have not yet been extensively used to facilitate agricultural innovation processes.

Box 2-1: Examples of m-services to facilitate information exchange and learning

M-surveys: The Technoserve Coffee Initiative in Tanzania uses the mobile phone-based survey application *FrontlineForms* to evaluate the impact of training on farmers' behaviour and yield changes (Oyenuga, 2011). In Uganda, data collection is also offered through the *Community Knowledge Worker* (CKW) programme where data is collected from farmers by sending them questions via SMS or by designing mobile surveys through *ODK Collect* which are then carried out by CKW staff.

Social networking: *Sauti ya wakulima* (The Voice of the Farmers) in Tanzania 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.

Advice on farming practices: Some advisory m-services are delivered through SMS, such as *Reuters Market Light* (*RML*) which sends personalised information to Indian farmers. Other services use voice-based systems because of literacy or language barriers and the limits of SMS to convey complex information. Technologies include interactive voice response (IVR) (e.g. the *National Farmers Information System* in Kenya), voice recordings to respond to queries (e.g. *Knowledge Help Extension Technology Initiative*[5] in India), helplines (e.g. *IKSL – IFFCO Kisan Sanchar Limited* in India) or radio programs that respond to questions sent via mobile phones (e.g. *The Organic Farmer* in Kenya).

[5] Haider Rizvi and Dearden (2010)

Information related to the production environment: The government-run *Radio and Internet for the Communication of Hydro-Meteorological Information* project in Zambia disseminates weather information collected from farmers (sent by SMS) and satellites (Mumbi and Ghazi, 2011). Regarding disease outbreak information, Makerere University is trialling a system to monitor cassava crop disease outbreaks in Uganda using camera phones with Global Positioning System (GPS). Maps showing disease outbreaks area then displayed on a website.

Training: In India *Lifelong Learning for Farmers* offers learning modules as recorded audio content delivered to female livestock producers through mobile phones (World Bank, 2011).

2.1.2 Financial services

Various financial services can facilitate the adoption of agricultural technologies. Transmission services, for instance, can be used to pay for technologies or other inputs and to sell the produce. Access to loans can provide farmers with the necessary financial resources to purchase technologies and associated inputs, to cover for production losses if they set aside part of their land for experimentation and to increase their willingness to bear the financial risk in case the technology does not perform well. Banking facilities can also help farmers manage and earn interest on their savings, thereby enabling them to better deal with the seasonality of agricultural income and increase the choice of when and where to purchase which inputs rather than being limited to the time when income is available or to obtain inputs from their creditor. Finally, famers may be more willing to adopt new technologies if their financial risks were reduced through insurance to protect against crop failure.

However, banks are often hesitant to expand into rural areas since servicing small-scale farmers can incur high transaction costs due to the small-scale deposits, dispersion of the population and poor infrastructure (Poulton et al., 2006). Similarly, monitoring and paying out dispersed and small insurance claims can be costly for the insurer. In these cases, financial services may be more profitably delivered through m-services which reduce the need for physical banking facilities and visits to insurance claimants. Among relevant services, m-payment schemes have been proliferating most rapidly in developing countries. These schemes are often initiated by mobile network operators (MNOs) which have the necessary infrastructure to run the service (IFC 2011).[6] More recently, MNOs in cooperation with local banks have started expanding into mobile-phone enabled bank accounts and loans. Insurance providers are also exploring the use of m-payments schemes in combination with sensors to record e.g. rainfall to monitor and pay out insurance claims.

[6] For an overview of global mobile money deployments, see www.wirelessintelligence.com/mobile-money

Box 2-2: Examples of m-services offering financial services

Transmission services: One of the earlier and more successful examples is *M-Pesa*, an m-payment system launched in 2007 by the Kenyan MNO Safaricom in collaboration with Vodafone.

Savings: The Nigerian Diamond Bank offers the *Diamond Y'ello Account* to all registered MTN customers as a full bank account with interest payments on account balances.[7]

Loans: The Development Bank of Jamaica launched the *M3 Mobile Money for Microfinance* pilot project in 2013 in collaboration with the National Commercial Bank Jamaica Ltd., Transcel Global Mobile Transactions and microfinance institutions, which enables subscribers to access and repay microloans through their mobile phone (DBJ, 2013).

Insurance: In Kenya, *ACRE* insures crops against extreme weather events. In case of extreme drought or excess rain (measured by weather stations), pay-outs are automatically transferred to insured farmers via *M-Pesa*.

2.1.3 Agricultural inputs

The use of new agricultural technologies for experimentation or adoption often requires a bundle of technologies and other farming resources, such as seeds, fertiliser, pesticides, labour, machinery, energy, storage facilities and irrigation. Accessing these resources will need well-functioning labour and input markets which can be a serious constraint in particular in remote areas characterised by underdeveloped infrastructure, dealer networks and product support (Sunding and Zilberman, 2001). Also, seasonal and small-scale demand may not provide a sufficient incentive to develop the necessary market infrastructure (Poulton et al., 2006).

Only a few m-services are facilitating access to agricultural inputs, for instance by offering information on input suppliers or input prices. Mobile phones could also facilitate collective purchasing of inputs to create economies of scale and reduce transaction costs. Moreover, mobile phone-enabled financial services outlined in the previous section will facilitate the procurement of inputs. Some services are supporting access to water which has been identified as one of the most important factors explaining differences in agricultural technology adoption patterns (Feder & Umali 1993, Barker et al. 1985). For instance, mobile phones are being used to manage irrigation systems or to pay for water. Mobile phones also facilitate access to electricity, although somewhat indirectly. MNOs have been providing excess power from their base stations to local communities. M-payments have also been used to pay for electricity. Finally, some virtual labour markets have also been set up, although their use in the agriculture sector is still limited.

[7] For other examples, see www.gsma.com/mobilefordevelopment/programmes/mobile-money-for-the-unbanked/insights/tracker (accessed 8 February 2015).

Box 2-3: Examples of m-services facilitating access to agricultural inputs

Agricultural inputs: The *CKW* program in Uganda provides a directory of input suppliers, including location and contact information, which farmers can access through an SMS-searchable database. The *National Farmers Information System* in Kenya disseminates price information on inputs.

Water: The *Nano Ganesh* device in India enables farmers to switch water pumps on and off using their mobile phone (Ribeiro, 2009). In Kenya, farmers using *Grundfos LIFELINK* in Kenya can charge a smartcard via *M-Pesa* to pay for water.

Electricity: In Kenya Safaricom has laid min-grids to supply power from its base stations for local infrastructure, such as water pumps and lighting (Roach and Ward, 2011). Also in Kenya, *Shared Solar* allows users to credit their electric account via SMS similar to charging prepaid phones (Ulbricht, 2011).

Labour: The *Berendina Employment Resources Centre* in Sri Lanka enables employers and job seekers to register with the service by phone. Their details are entered into a web-based database which can match labour demand and supply.

2.1.4 Output markets

Expected financial returns will motivate farmers to experiment with new technologies or adopt them on a large scale. Limited information on market prices and the resulting uncertainty about expected returns can provide a disincentive for farmers to try out or adopt new technologies (see also Section 4.1). To date, many farmers in developing countries rely on middlemen to receive market information, given that search costs for finding information elsewhere are often high (Eggleston et al. 2002). Better access to market information can reduce information asymmetries between farmers and traders, thereby allowing farmers to negotiate fairer prices (ibid). The information also enables farmers to better assess the financial risk and expected profitability of investing in new agricultural technologies (Marra et al. 2003). Various m-services provide information on market prices for crops and livestock, often as part of a broader information package. Price information might be sent on demand or via automatic updates.

The ability to profitably sell surplus produce for income generation will also depend on good access to markets. Mobile phones-enabled 'virtual' markets for agricultural products can help farmers link up to alternative buyers or markets (provided that physical access constraints, such as lack of roads, do not prevent farmers from selling their goods). Another expanding m-service includes supply chain management systems which use mobile phones and other wireless devices to manage produce sales. Such services can help to reduce transaction costs associated with sourcing from a large number of small dispersed farms.

Box 2-4: Examples of m-services facilitating participation in output markets

Market prices: *Esoko* in Ghana sends automatic updates on the prices of agricultural commodities to subscribing farmers. *M-Farm* in Kenya sends out price information on demand through a SMS-searchable database (see Section 4.3 for further details).

Market access: The mobile application *iCow Soko* in Kenya enables producers to buy and sell livestock and livestock produce across its mobile platform. In many cases, services to trade agricultural goods are integrated into broader trading platforms where users can buy and sell a variety of products, such as *Cellbazaar* operated by Grameenphone in Bangladesh.

Supply chain management: The Rural Sourcing Management software developed by SAP and deployed in Ghana facilitates sourcing of shea through the *Star Shea Network* and cashew through the *African Cashew Initiative* (Rohwetter 2011). Similarly, the Kenyan company Virtual City uses mobile phone technologies to track produce deliveries from small farmers to processors and sellers through its *Agrimanagr* service. Another example is *Farmforce* developed by the Syngenta Foundation, a tool to organise a large number of smallholder farmers who supply a particular buyer. The tool includes a software platform which manages information received from farmers via their mobile phones, as well as other feature, such as documentation, traceability, and compliance with the required standards (Wills, 2013). *Farmforce* was first trialled in India and Kenya.

2.1.5 The role of technological change

The mobile sector is highly dynamic. Mobile phones and related services have been evolving rapidly and will continue to do so in the future. The expansion of mobile networks and the development of affordable mobile phones have made the provision of m-services possible in the first place. Improving network speeds and technical advances in mobile technologies allow for increasingly sophisticated services to be offered (see Chapter 3 for more details on technological advances in mobile hardware). As a result, the reach, diversity and complexity of m-services is changing over time, which can impact the provision of m-services in a number of ways:

Some m-services exhibit network externalities, i.e. m-service users benefit from the addition of new users (Torero and Braun, 2006). Examples include social networks, m-payments and virtual output markets. These services usually require a critical mass of subscribers before they become useful. Adoption is often characterised by long lead times followed by explosive growth (Shapiro and Varian, 1999). Once a critical mass is reached, the service becomes attractive to other users because it is widely used, thus generating positive feedback and offering the service providers a competitive advantage over others with a smaller customer base (ibid).

Attaining critical mass and a diverse user base can also have implications for the affordability of m-services and thus their reach to poorer farmers. A large base allows the service provider to offer the service at a smaller fee. Alternatively, a diverse user base allows for differential pricing where payment for premium services (e.g. additional features or faster access) can be used to cross-subsidise services offered to less well-endowed users.

As some m-services get widely adopted, they can stimulate the provision of other services. For instance, developers may integrate existing services into their new service. Mobile payment services in Kenya are a good example. Following the spread of m-payments across the country and deep into rural areas, other service providers are now using m-payments to offer their services to farmers, such as output markets (e.g. *M-Farm*), insurance schemes (e.g. *ACRE*) or water provision (e.g. *Grundfos LIFELINK).*

The expansion of agricultural m-services may also incentivise the provision of complementary services. Over the past two decades researchers have increasingly recognised the need to look at agricultural technologies as a package where farmers may adopt components at different times and speeds (Feder and Umali, 1993). For instance, m-services offering information on the correct use of inputs, such as pesticides or fertiliser, coupled with access to loans to finance the inputs could stimulate demand for input suppliers and for m-payment schemes to purchase the inputs.

Also, individual farmers may move up the 'technological ladder' – both in terms of agricultural and mobile technologies – thereby offering opportunities to develop new m-services that respond to evolving demand and technological capabilities. Various studies find that smallholder farmers tend to adopt simple agricultural technologies first before moving on to more complex ones, while cheaper technologies may be adopted before more expensive ones (Kaliba et al., 2000). M-services could facilitate the adoption of simple technologies (e.g. improved seeds accessed through virtual input markets) which in turn creates demand for more advanced technologies and related m-services (e.g. mobile phone-enabled irrigation systems). Similarly, farmers may start off with simple SMS-based information services accessed via basic phones, and then move on to higher-end phones and more sophisticated services as their incomes, technical know-how and information needs grow.

2.2 Empirical Evidence and Research Gaps

The first empirical study on the role of mobile phones in poverty reduction and rural development was carried out by Bayes et al. (1999) who assessed the impact of the *Village Pay Phones* in Bangladesh, an initiative of the Grameen Bank which leases cellular mobile phones to selected members. Since then, a growing body of literature has emerged in this research field. The following literature review summarises key findings from empirical studies assessing the impact of mobile phones and m-services in developing countries. The focus is on studies that examine impacts on farmers and rural communities in particular. Studies dealing with related sectors (e.g. fisheries or small businesses) or on users more generally are cited where the findings are relevant to the agriculture sector.

The papers were identified using academic databases (e.g. Science Direct, IDEAS) and internet search engines (e.g. Google) with combinations of keywords such as mobile phone, agriculture, technology adoption, poverty etc. In addition, the snowball method was applied to identify relevant literature from reviewed articles. Unless otherwise stated, the reviewed studies either address mobile phones specifically or disaggregate data for mobile phones and other telecommunication media. With the exception of Bayes et al. (1999), only studies were selected that were published (or use data) after 2000 when mobile penetration rates started to expand significantly in developing countries.

Three of the reviewed studies assessed the use of mobile phones on agricultural production and productivity more generally:

- In Tanzania, Furuholt and Matotay (2011) find that mobile phones affected all stages of farming cycle, including preparations, farming, harvesting and post-harvesting. Overall, farmers felt that mobile phones had helped to raise incomes by improving their ability to deal with risks and take advantage of income opportunities.
- In Uganda, Martin and Abbott (2011) also conclude that farmers used their phones for a range of farming activities, especially to coordinate access to agricultural inputs (such as training, seeds or pesticides) (87% of farmers), accessing market information (70%), requesting agricultural emergency assistance (57%), monitoring financial transactions (54%) and consulting with expert advice (52%)
- A study in Peru observes that the introduction of mobile pay phones in selected Peruvian villages had raised agricultural profitability by 19.5% by increasing the value that farmers received for each kilogram of agricultural production by 16% and reducing agricultural costs by 23.7% (Beuermann, 2011). The study outlines possible mechanisms through which ICT access can increase profitability (e.g. reduced search costs to find the best market, better bargaining power due to knowledge of prices, access to weather information), but did not assess how these mechanisms played out in the Peruvian context.

The remainder of the reviewed studies are analysed using the four categories identified above (information and learning, financial services, agricultural inputs and output markets) to assess available evidence and identify research gaps.

2.2.1 Information and Learning

Various studies have examined the role of mobile phones in facilitating access to **information**. Several assessments conclude that mobile phones had reduced search times and costs (Bayes et al., 1999; Beuermann, 2011; Jagun et al., 2007; Overå, 2006) as well as information asymmetries (Overå, 2006). In the case of *Village Pay Phones* in Bangladesh, for instance, such cost reductions had benefited in particular the poor, resulting e.g. in better access to and prices for outputs and inputs, and a more stable supply of fertilisers and fuel (Bayes et al., 1999). A study in Nigeria also finds, however, that mobile phones had not necessarily improved the quality of information, but rather its completeness (Jagun et al., 2007).

Different studies have come to different conclusions regarding the extent to which farmers use mobiles to actively search for agricultural information. Studies of mobile phone use in rural areas of China, India, Kenya, Mozambique, Sri Lanka and Tanzania note that phones were hardly used for knowledge gathering (Campaigne et al., 2006; de Silva and Ratnadiwakara, 2008; Okello et al., 2010; Oreglia et al., 2011; Souter et al., 2005). In most cases agricultural information was mainly obtained through face-to-face contacts. In contrast, other studies of fishers in India and farmers in Tanzania find that mobiles were used to access market information for their produce (Jensen, 2007; Sife et al., 2010). One study in India suggests that differences in the use of phones for information search may be explained by the profitability of agriculture in the region. Thus, farmers more actively sought information in areas where agriculture was profitable (Kameswari et al. 2011). Mobile phones may also be more useful in the case of perishable crops (see below).

Only a few studies have assessed the use and impact of dedicated m-services to disseminate information. Existing studies have focused on m-services offering farming, weather and price information (see Sections 2.1.4 and 4.1 for a review of studies examining price information services).

Regarding farming information, a service disseminating information on the correct use of nutrients via SMS and voice alerts in India had led to a perceived 15% increase in incomes among intervention farmers compared to the control group, mainly through cost reductions due to the application of appropriate (i.e. lower) amounts of seeds and nutrients (Raj et al., 2011). Farmers were given individualised instructions for nutrient management and other crop cultivation practices via SMS and voice alerts which they were then required to implement. The observed benefits might thus say more about the utility of the instructions than the mobile phone as a dissemination tool. Farmers could also access information on demand via IVR, but it is unclear what information they accessed and how it might have impacted production practices.

Two studies assessed the impact of voice-based information services, including IVR and helplines. A study of *LifeLines*, a telephone-based advisory service for Indian farmers, finds that the majority of farmers reported that the service had improved their productivity, increased savings and earnings and decreased the need for loans (Haider Rizvi, 2011). Also in India, the use of the information service *Avaaj Otalo*, which was developed as a collaborative project between two US universities, the IBM India Research Laboratory and an Indian non-governmental organisation (NGO), led to reported changes in management practices, including increased use of effective pesticides and more extensive adoption of the lucrative but risky crop cumin (Cole and Fernando, 2012). Interestingly, most farmers appear to accept the advice on face value, but did not show improved agricultural knowledge overall.

Two studies looked at the impact of weather information sent by SMS to farmers. One study in Colombia concludes that farmers who received weekly weather information suffered 4-7% less weather-related crop losses compared to the farmers in the control group who did not receive this information (Camacho and Conover, 2011). In contrast, Fafchamps and Minten (2012) do not find that Indian farmers who were sent regular weather updates through *RML* were able to reduce crop losses after storms compared to control farmers.

While the potential of mobile phones in the provision of agricultural extension services has clearly been recognised (e.g. Aker 2011), the use of mobile phones to facilitate **education and learning** has hardly been assessed empirically. One study examines the impact of the *Lifelong Learning for Farmers* initiative where training modules are recorded and disseminated to female livestock producers via mobile phones (Balasubramanian et al. 2010). The study concludes that the participants regard mobile phone-based training as useful and more convenient than face-to-face contacts because they could access the recordings at a time and place that suited them.

2.2.2 Financial Services

Research on the use of mobile phone-enabled financial services in the agriculture sector (including m-banking, loans and insurance) is very limited. The one empirical study in this area examines the use of mobile payments by Kenyan farmers (Kirui et al., 2010). The study finds that around half of the farmers used mobile phones to make and receive transfers, primarily through *M-Pesa*. The use of m-payment services was more widespread in areas with higher agricultural commercialization. Further distance to banks, higher education levels and higher capital endowments also increased the likelihood of farmers using m-payments. However, only a small share of payments was used to pay for farming-related items, including inputs (7%) or farmworkers (6%). Most of the money went towards non-agricultural uses, such as paying school fees, meeting regular non-food household needs or repaying debt.

2.2.3 Agricultural Inputs

Hardly any research has examined the use of mobile phones to obtain agricultural inputs. Bayes et al. (1999) observe that supply of inputs for vegetable growers, such as fertiliser or diesel, was smoother and more stable in villages with mobile pay phones. The mobile phones had also lowered input costs of livestock producers by enabling them to contact different markets. There is also some evidence from East Africa, Bangladesh and Latin America that access to mobile phones in general had facilitated job searches (Bayes et al., 1999; Mascarenhas, 2010) and the coordination of informal job market (Galperin and Mariscal, 2007). An impact assessment of the *Berendina Employment Resources Centre* in Sri Lanka, however, finds that hardly any users took up the job offers received through the Centre because they did not trust offers received over the phone (Balasuriya and de Silva, 2011).

2.2.4 Output markets

Studies into the role of mobile phones and m-services in facilitating marketing of produce have mainly focused on the use of mobiles to access price information and their impact on producer-buyer relationships. This section summarises key findings of these studies. For a more detailed discussion, see Section 4.1.2.

Several studies, which examine how the expansion of mobile phone networks has impacted prices, observe greater effects in the case of perishable than non-perishable products. Muto and Yamano (2009) note that the network expansion had a positive and significant impact on the price ratio of banana, but not maize. The impact was larger for those farmers located closer to district centres, suggesting that more remote farmers may be less informed about prices even with access to mobile phone networks. Two studies conclude that network expansion had decreased price dispersion for perishable products, including for fish in India (Jensen, 2007) and cowpeas (Aker and Fafchamps, 2011) in Niger. In contrast, also in Niger no effects were observed for millet and sorghum which are less perishable and are commonly stored by farmers (Aker and Fafchamps, 2014).

Evidence on the impact of price information m-services on income gains is not clear cut. Two experimental studies in Bangladesh and Sri Lanka find that the information had helped farmers to obtain higher prices (Islam and Grönlund, 2010; Lokanathan et al., 2011). In contrast, research in Colombia (Camacho and Conover, 2011) and two studies in India (Fafchamps and Minten, 2012; Mitra et al., 2013) do not detect price gains. Anecdotal evidence from Sri Lanka and Uganda suggests that the price information has helped farmers decide on the best time to harvest and sell (Ferris et al., 2008; Lokanathan and de Silva, 2010).

Several studies have assessed the impact of mobile phones on producer-buyer relationships. Only a small number conclude that mobile phones had induced producers to change their selling patterns, e.g. by encouraging them to move to other markets (Jensen, 2007) or enabling them to bypass middlemen (Boadi et al., 2007). Muto and Yamano (2009) also find that following the introduction of the mobile network, banana farmers from remote areas had managed to increase sales (as a share of households selling bananas and the share of production sold[8]). The mobile network had no impact on maize sales, possibly because maize is less perishable and therefore not as urgent to sell.

Most studies, however, conclude that mobile phones have had limited effects on producer-buyer relationships because many farmers were unable to take advantage of more marketing choices. Obstacles include the perceived need to build trust through direct contact, the perishable nature of the produce, limited storage facilities and lack of alternative markets (Frempong et al., 2007; Galperin and Mariscal, 2007; Goodman, 2005; Jagun et al., 2007; Kameswari et al., 2011; Molony, 2006; Overå, 2006). Similar findings also emerge from studies of the m-services *PalliNet* in Bangladesh (Islam and Grönlund, 2010) and *TradeNet* in Sri Lanka (Lokanathan et al., 2011).

Empirical research into the effectiveness of mobile phone-enabled supply chain management systems is still limited. An in-company review of *Agrimanagr*'s performance shows that the system had reduced the delay in payments to farmers from 120 to 31 days due to a faster consolidation of report, cut purchasing times from 3 minutes to 22 seconds, and increased the average produce weight per transaction by 9-13% with the use of electronic weighing technologies.[9]

2.3 Inclusion – Reaching the Marginalised and Poorest?

This section reviews existing evidence on the potential of mobile phones and m-services to assist in particular the poorest and marginalised farmers and assesses the challenges they face to benefit from related services.

2.3.1 Access to mobile phones

Several studies conclude that the wealthier and more educated are more likely to own mobile phones (e.g. Mascarenhas 2010; Muto & Yamano 2009; Souter et al. 2005).[10] In addition, mobile phone ownership rates vary between urban and rural areas, although the evidence is somewhat scattered in the absence of comprehensive data. A Gallup survey carried out in 17 Sub-Saharan African countries in 2010 finds that 69% of respondents living in urban areas owned a mobile phone compared to 53% in rural areas (Gallup, 2011). However, while ownership tends to be higher among wealthier users, income does not necessarily seem to be as significant a barrier to *accessing* mobile telecommunications, including through phone sharing which appears to be particularly prevalent among lower-

[8] It is unclear whether this increase is due to production increases or increases in the share of bananas sold rather than e.g. being consumed or perishing.
[9] Key informant interview, May 2012; Virtual City (2009)
[10] It is interesting to note, however, that mobile phone ownership in Tanzania and South Africa was found to be less biased towards wealthier segments of the population than other consumer durables (Samuel et al., 2005). The authors conclude that "on the whole, mobile is very far from a luxury good affordable by only the rich" (p.47).

income groups (see Box 2-5). To date, the dynamics of shared phones outside of formal phone shops remain poorly understood (Donner, 2008).

> Box 2-5: Challenges in assessing mobile phone usage
>
> Mobile phone subscription data alone offer only a distorted picture of mobile phone usage in developing countries since they do not take into account multiple SIM card ownership, inactive SIM cards and phone sharing (James and Versteeg, 2007). The GSM Association estimates global unique subscriber penetration rate at 45%, less than half the total connection penetration rate of 93% (in Q4 2012) (GSMA, 2012a). In developing countries, the unique penetration rate is thought to be 39% compared to 87% total penetration rate while the difference between rates is less pronounced in developed countries (79% compared to 122%). Only 33% of people in Africa and 40% in Asia are thought to hold a subscription. The reliability of these figures is difficult to ascertain. Ericsson, for instance, estimated actual global subscription rates to be higher at 63% compared to 90% total penetration (in Q1 2013) (Ericsson, 2013).
>
> At the same time, subscription rates are likely to underestimate the access that people have to mobile phones through sharing with family and friends or using pay phones. Per capita subscription data tends to underestimate in particular phone usage among lower income groups and in rural areas where phone sharing is widespread. While no global statistics are available, country surveys in Africa and Asia point to a high prevalence of phone sharing (e.g. Gillwald 2005; Goodman 2005; Samuel et al. 2005). A study in Sri Lanka, Pakistan and India, for instance, finds that over 90% of respondents had used a phone in the last three months, even though 59-81% of those from lower income groups had to borrow someone else's phone (de Silva and Zainudeen, 2007). Thus, 'mobile phone user', i.e. people who actually use a mobile phone (including their own or someone else's) would provide a more useful indicator to measure mobile phone penetration. However, nationally comparable data on usage are not available.

2.3.2 Benefits from mobile phone use

Several studies conclude that the better-off benefit more from mobile phone use. A study of micro-enterprises in Nigeria finds few signs "of mobile telephony leveling the playing field; and more signs that it had been a technology of inequality" (Jagun et al., 2007, p. 62). The most-resourced microenterprises who owned a mobile had gained through more and larger orders, faster turnaround and better product quality, while the least-resourced without access to mobiles were losing orders. Similarly, Souter et al. (2005) conclude that the mobile phone had benefitted higher status groups in India, Mozambique and Tanzania most while "the most marginalised could well be left behind" (p. 10).

On the other hand, some studies suggest that the poorest and marginalised may in fact have the most to gain from the use of mobile phones due to a lack of alternative means of communication. A business survey in South Africa and Egypt shows that mobile phones had benefited in particular the disadvantaged groups, including black-owned businesses in South Africa and informal sector businesses in Egypt, for whom mobiles were often the only source of telecommunications (Samuel et al., 2005). Similarly, a study of Ugandan farmers finds that smallholder farmer had profited most from the extension of mobile phone networks, possibly because larger farmers had already had other means of contacting traders and obtaining information (Muto and Yamano, 2009).

As noted above, little research has explored the dynamics of mobile phone sharing. One study comparing mobile phone owners, non-owning users and non-users observes that owners in Tanzania used phones for a greater variety of purposes while non-users mainly used phones to contact family members or for business reasons (Goodman, 2005). The study of Ugandan farmers also shows that households that did not own a mobile phone could still benefit from the availability of mobile phones in the community, for instance when someone in the village arranged collection of produce with a trader (Muto and Yamano, 2009). Similarly, users in Bangladesh benefited from the availability of shared mobile pay phones in their village (Bayes et al., 1999).

Relative costs and benefits may also be influenced by the share of income spent on mobiles phones. However, there is a lack of systematic data comparing monthly spending by income groups. Souter et al. (2005) note that poorer users in India, Mozambique and Tanzania spent a higher share of their income on the phones than high income groups, but do not quantify the difference. Other studies suggest that users spend between 4-10% of their income (Furuholt and Matotay, 2011), but do not distinguish between income groups.

In addition to these more tangible impacts, Gomez and Pather (2011) stress the need to also evaluate issues such as "empowerment, self-esteem, and sense of self-worth, at the individual level, and social cohesion and strengthening of social fabric, at the collective level" (p. 10). A survey in Pakistan, India, the Philippines and Thailand, for instance, finds that two-thirds of telephone owners surveyed felt that "ownership of a telephone has enhanced their social status and recognition in their community" (de Silva and Zainudeen, 2007, p. 11). Mobile phones in particular were regarded as more accessible for people from all socio-economic backgrounds, thereby "reducing the 'gap' between the rich and the poor leading to a feeling of 'upliftment' among the poor" (ibid).

A small number of studies also show that mobiles have the potential to both reinforce and redress gender imbalances. The assessment of *Village Pay Phones* in Bangladesh points to the empowerment and increased social status of phone-leasing women and their households (Bayes et al., 1999). The *Lifelong Learning Initiative* was also found to have contributed to gender empowerment by extending training opportunities to female livestock producers who previously did not have the time, resources or courage to attend face-to-face training (Balasubramanian et al. 2010). A case study of mobile phone use in Uganda, on the other hand, shows that gender inequality reinforced asset control by the husbands who sought to keep control over the phone while the women often felt that they were not benefiting from the new technologies (Diga, 2008).

Regarding the utility of m-services, evidence on the use of and benefits among different income groups is very limited. The above-cited study that differentiated between different types of farmers using *M-Pesa* suggests that the main users of m-payments are farmers in commercial agriculture areas with higher levels of income and education (Kirui et al., 2010).

2.4 Overarching Research Gaps and Methodological Challenges

A number of research gaps cut across the empirical literature on the usage and impacts of m-services. Very few studies have looked into different designs of m-services, e.g. how the service is delivered (e.g. voice, SMS, USSD/Unstructured Supplementary Service Data, internet), how it can be accessed (e.g. on demand or sent automatically) or how much should be charged. One study looking at a price information service compared groups of farmers that either received market information automatically (the 'push' group) or on demand (the 'pull' group) (Islam and Grönlund, 2010). The information was considerably more effective for farmers in the push than in the pull group.

Little research has examined how farmers' characteristics influence effective usage of an m-service. Assessing the role of ICTs in accessing market information more generally, Kiiza and Pederson (2012) find that the more commercially-oriented farmers who were located closer to markets, already sold their produce on the market, had access to microfinance and were members of a farmers cooperative were more likely to use the services. The study did not distinguish between different ICTs, however, nor did it differentiate between types of market information. In addition to farmers' characteristics, more attention also needs to be paid to the context in which farmers operate (e.g. distance to the market, the availability of inputs or social institutions) and how it shapes their propensity and ability to use different m-services.

Not enough research into m-services has assessed actual usage patterns, how impacts vary accordingly and the reasons why a service is not used. Rather, experimental studies tend to distinguish between users (or those with access to the service) and a control group, and then compare impacts for the entire groups. Haider Rizvi (2011), for instance, observes that the usage frequency of *LifeLines* was generally low and varied widely between weekly and twice a year, but does not differentiate by usage in the impact analysis. Similarly, Fafchamps and Minten (2012) note that only 59% of farmers who had been offered a free *RML* subscription to receive price and farming information actually used it, but carry out much of the analysis using data from farmers who had been offered the subscription.

The role of mobile phones vis-à-vis other channels also warrants further analysis. Jensen (2010) argues that it is the information and communication that is most important, not necessarily the technology used. However, there is little comparative data on different channels to deliver m-services. Comparing market information provided through radio and mobile phone, Ferris et al. (2008) find that farmers preferred to receive the information through the local radio stations even though almost all of them had access to a mobile phone. Many farmers were not aware of the price information service available through SMS and were not used to using their mobile phone to access business information. Traders, in contrast, were more likely to obtain price information through their mobile phones. However, the authors also predict that SMS will become more desirable in the longer term because they are cheaper and can be accessed and updated more easily.

At the same time, it is important to note that impact studies of mobile phones and m-services suffer from certain methodological challenges. Unpolluted experimental designs to assess the effects of mobile phones in general are no longer feasible due to the pervasiveness of the technology. Also, the systemic changes resulting from the introduction of mobile phones make it difficult to isolate any specific effects. This is also true in agriculture where mobile phones have been found to influence the entire production process (Furuholt and Matotay, 2011; Martin and Abbott, 2011).

Randomised control trials better lend themselves to the study of m-services since providers are able to control and measure usage of the service. However, such research nevertheless risk contamination since the conditions under which the interventions are implemented are often difficult to control (Barahona, 2010). For instance, in the case of publicly available m-services, anyone is free to subscribe. Lokanathan et al. (2011) find that although *Tradenet* was only mentioned to the treatment group, farmers in the control group had also heard of the service through word-of-mouth and advertising[11]. Avoiding contamination is particularly challenging in the case of information services given that information spreads easily (including through mobile phones). As outlined in the case study below, *M-Farm* users readily shared the price information they received with others, including non-users.

In addition, the impact of the m-service can be difficult to isolate from the use of the phone in general. If farmers are introduced to an m-service, it may induce them to use their phone more readily for other purposes. As will be discussed below, women farmers interviewed for the case study said that after learning to use the mobile through *M-Farm*, they started using the phone for other business transactions as well. One study tried to deal with this challenge by preventing participants from using the mobile phone they received to access the service to make or receive other calls (Mitra et al., 2013). However, the researchers would not be able to prevent participants from using their own phones.

Establishing causality between m-service use and observed changes in agricultural production is difficult if the research relies primarily on farmers to report impacts. For instance, many *RML* subscribers in India attributed production changes to the service even though the statistical analysis does not find significant differences between the treatment and control groups (Fafchamps and Minten, 2012). Where an m-service offers several functions, isolating impacts becomes even more complex. Users may also not be able to distinguish between the role of the m-service vis-à-vis other factors. Section 4.4 elaborates how these constraints apply in the *M-Farm* case study.

Finally, studying the role of m-services in agricultural innovation processes poses a particular challenge since similar factors may influence farmers' use of m-service and their involvement in innovation processes. Indeed, studies of the respective influencing factors have come to some similar conclusions (see Chapter 4 for further details).

[11] The authors do not provide data on whether and how participants in the control group used the service.

3 Mobile Technology Trends and Agricultural Development: Status and Outlook Globally and in Kenya

This chapter provides a brief overview of the status of mobile technologies and m-services in the developing world. It then discusses new mobile technology trends and their potential to promote agricultural innovation. To this end, the chapter identifies three such 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 a large user base and social networks to gather data, collectively develop solutions and facilitate learning.

All three trends mark a shift in the way that individuals and companies use mobile devices, i.e. from single devices providing certain services to 'ecosystems' of diverse interconnected devices that offer multiple services (Taylor, 2012). The chapter 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 chapter identifies some of the key factors and outlines two possible scenarios under different assumptions.

The analysis in this chapter goes beyond mobile phones to deal more generally with mobile connected devices which are understood to include all connected devices (as defined by the GSM Association[12]) that use wireless networks, e.g. mobile personal computers (PCs), tablets, routers, mobile phones and certain machine-to-machine communication (M2M) devices. For the purpose of this chapter, mobile connected devices are divided into two categories, namely personal mobile devices (i.e. devices that allow users to access m-services, see Box 3-1 and Figure 3-1) 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).

The chapter concludes with an assessment of m-service provision in Kenya's farming sector. The section identifies the factors that have driven the emergence of local m-service providers and highlights remaining challenges for the sector. It also reviews existing agriculture-related m-services already offered to Kenyan farmers that facilitate access to information, financial services, inputs and output markets.

[12] 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" (GSMA, 2012b, p. 3).

Box 3-1: 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 WiFi and GPS

Tablet: Smartphone 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 tones via keypad

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

USSD: Unstructured Supplementary Service Data, a synchronous message service creating a real-time machine-to-people 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 et al. (2013, p. 42) and Ericsson (2013, p. 6).

Figure 3-1: Personal mobile devices and delivery technologies

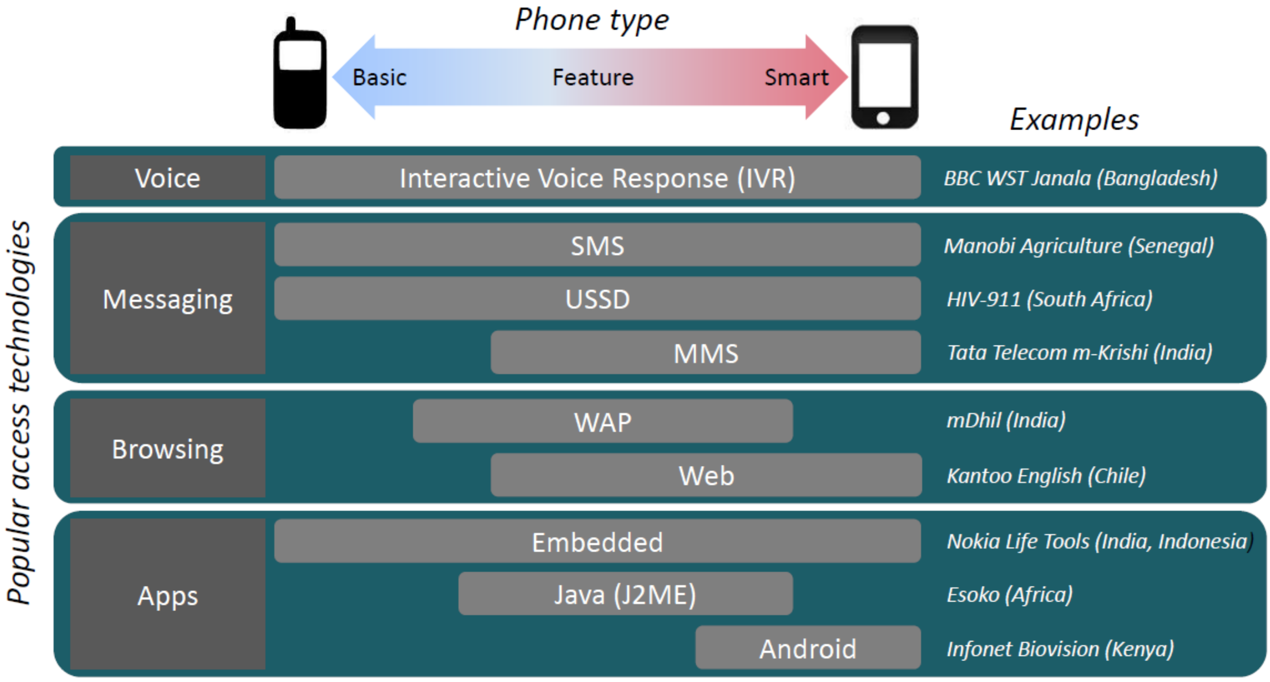


Image © Mobile for Development Impact (Hatt et al., 2013).

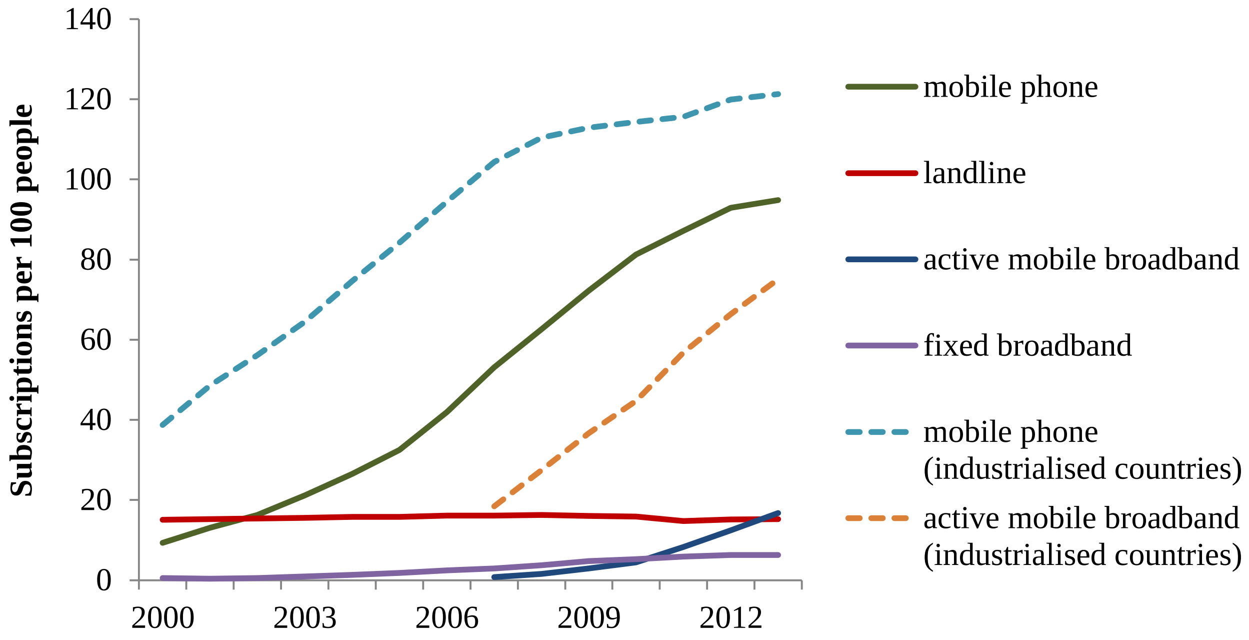
3.1 Global Mobile Technology Trends and their Potential for Agricultural Development

3.1.1 Development and status of mobile technologies in developing countries

Among mobile connected devices, mobile phones have seen by far the fastest growth in developing countries, many of which have largely leapfrogged fixed lines to move straight to cellular technologies. By 2013, subscribers from developing countries accounted for 78% of the 6.9 billion global subscriptions, up from a third in 2000.[13] Much of that growth has been driven by the Asia-Pacific region. While developing countries still lag behind industrialised countries in terms of subscription rates, the gap has slowly been closing since 2008 (Figure 3-2). The growth in mobile phone subscription rates in developing countries has dwarfed that of fixed telephones, with an annual growth rate of 20% between 2000 and 2013 compared to 0.01% annual growth in fixed lines. In recent years, mobile broadband rates have also outpaced fixed broadband, growing at an impressive rate of 66% annually between 2007 and 2013.

[13] Subscription rates should be read with caution as they do not account for multiple SIM card ownership, unused SIM cards or phone sharing, thus offering only a partial insight into the actual access to and use of mobile phones (see also Box 2-5 for a discussion of related data issues).

Figure 3-2: Telephone and broadband subscription rates (2000-2013)



Note: Unless otherwise stated, the figure shows subscription rates for developing countries. Data for mobile broadband subscriptions are not available prior to 2007.
Data source: ITU statistics, www.itu.int/en/ITU-D/Statistics (accessed 9 September 2014)

For now, basic and feature phones are still dominant in developing countries where less than 10% of people are estimated to own 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 (Hatt et al., 2013) finds that 85% of services are targeted at basic or feature phones.[14] Only a third are developed for smartphones (mainly in m-learning and m-entrepreneurship), slightly more than for PCs (31%). 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 IVR) due to their complexity and cost.

Farming-related m-services only constitute a small share of m-services available in developing countries where developers have largely focused on m-health, mobile money and m-learning services (Hatt et al., 2013). Among the examples mentioned in Chapter 2, delivery technologies on mobile phones mostly include SMS (e.g. searchable database or regular updates) and to a lesser extent IVR, voice recordings, helplines or the web. 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.

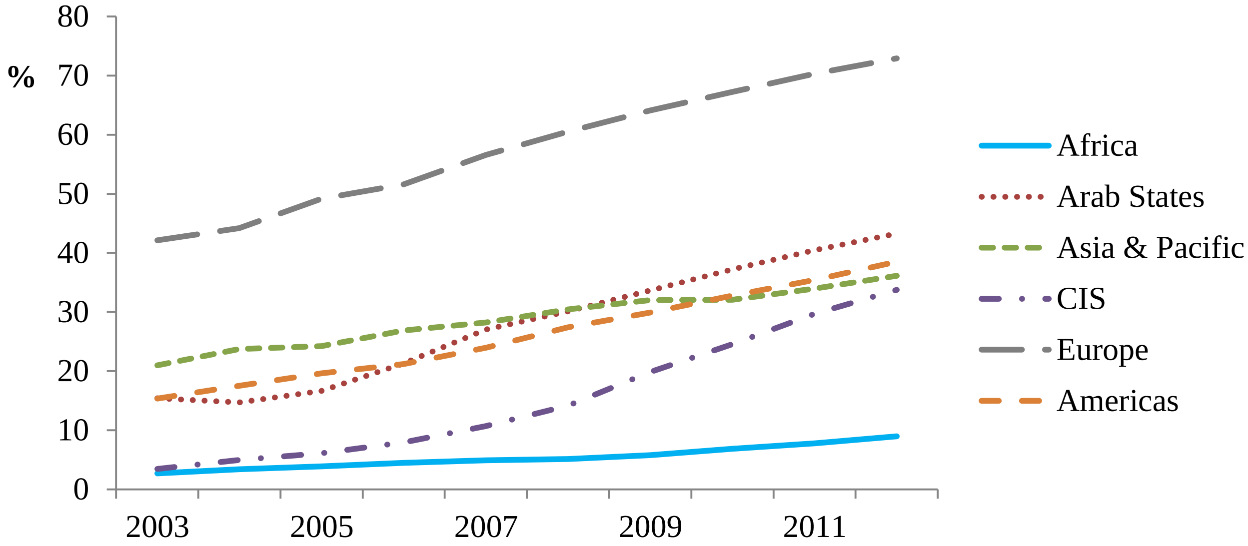
Other devices to access the mobile network include mobile PCs (including laptops and desktop PCs) and tablets. This functionality is becoming easier and more cost-effective, for instance through cheap external USB dongles, built-in WiFi or by using mobile phones as mobile hotspots. In particular laptops are often equipped with built-in wireless

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

connections. PC ownership is still low in the developing world. By 2013, 32% of households were equipped with a PC or laptop compared to 74% in industrialised countries.[15] Africa, where computer ownership rates have only started to pick up slowly since 2008, lags furthest behind with just 10% of households owning computers (Figure 3-2). 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).

Tablet use in most developing countries is also low (although no official statistics are available) and just 9% of services reviewed by Hatt et al. (2013) were developed for tablets. 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* 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.

Figure 3-3: Share of households with a computer (by region, 2003-2013)



Data Source: ITU ICT-Eye, www.itu.int/icteye (accessed 9 September 2014)

3.1.2 New Technology Trends

Many of the m-services currently available in developing countries 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

[15] ITU ICT-Eye, www.itu.int/icteye (accessed 9 September 2014)

lived up to expectations, even in countries with more advanced agriculture 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 US$ 4 billion have been invested in new submarine cables, almost doubling the data capacities in just two years (Schumann and Kende, 2013). By 2012, 40% of the Sub-Saharan African population 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:

Diversity of personal mobile devices and delivery channels

Personal mobile devices

The diversity of devices for accessing mobile services has been increasing in recent years. Basic and feature phones are slowly being displaced by smartphones in many industrialised countries, and tablets complement desktop PCs and laptops. Smartphone use is growing faster than expected. While Ericsson in 2012 predicted the total number of smartphone subscriptions to reach 3.3 billion by 2018 (Ericsson, 2012), the estimate was revised to 4.5 billion just one year later (Ericsson, 2013). The most recent projection puts the number of smartphones at 5.6 billion by 2019, accounting for 62% of total subscriptions (up from 19% in 2012) (Ericsson, 2014). 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).

As noted above, 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 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 June 2014, Google announced it ambitious Android One program aimed at offering high-quality and affordable smartphones to customers in emerging economies, starting in India in autumn 2014 (Pichai, 2014). As smartphones become cheaper, companies may compromise on quality of build and battery power which could be particularly problematic for rural areas (Hatt et al., 2013).

Data on global mobile subscriptions also highlight the growing importance of smartphones to access the internet through the mobile network. Smartphones with mobile subscriptions far outnumber mobile computers globally. Ericsson (2014) estimates global mobile subscriptions for PCs, tablets and mobile routers at just 300 million compared to 1.9 billion smartphone subscriptions in 2013. While the number of mobile computers is projected to increase to 700 million by 2019, they will still be dwarfed by the 5.6 billion projected smartphones. Total mobile data traffic via smartphones is expected to grow around ten times between 2013 and 2019.

However, some observers warn against overestimating the importance of smartphone expansion in developing countries. 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).

Tablets may offer a viable alternative to PCs in the developing world. Globally, tablet shipments have been growing rapidly and are expected to exceed portable PCs in 2013 and the entire PC market in 2015 (IDC, 2013a). 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). These features also make them attractive for internet cafés, as seen for instance in Senegal where the first Tablet Café opened in 2013 with funding from Google. Their adoption in developing countries will 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 five tablet producers and together account for 26% of tablet sales in India.

When it comes to smartphones and tablets, different software platforms are becoming increasingly important in influencing buyers' decision on which phone to purchase. Android and Apple's iOS are by far the main operating systems, accounting for 79% and 15% of all smartphone shipments in 2013 respectively (IDC, 2014). The Android operating system is particularly popular in developing countries due to the lower cost of devices and the system's flexibility through open source (Hatt et al., 2013). As popular platforms expand and crowd out smaller competitors, m-service providers that offer their service as a platform application can also expand their reach to potential customers without having to develop different versions for different platforms. Also, as more and more services are offered on a certain platforms, its popularity increases, thus creating a feedback loop.

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 centralised (and perhaps virtualised) data center to a mobile device such as a smartphone" (Taylor et al., 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 et al., 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 and 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 virtualised 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 authors 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.[16] 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 that required to run 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 3-2). 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.

Box 3-2: Battery life

The choice of phone and its usage 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 every 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 current 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.

Mobile phone manufacturers are already working on extending the battery life of their phones, for instance by improving the efficiency of the battery itself, the power-efficiency of the hardware (in particular the chip) or the processing power needed to run software

[16] www.binu.com

(Wagner, 2013). The Midia InkPhone, for instance, which was developed by the Chinese manufacturer Onyx, is a combined smartphone and e-book reader which only needs to be charged every 1-2 weeks thanks to its energy-saving display (Onyx, 2014). Another example is the Nokia Asha 501 which offers 17 hours of talk time and 48 days of standby time before needing to recharge the battery (Bean, 2013). The phone, which was launched in May 2013, is targeted specifically at consumers in emerging markets. 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.

Limited battery lives can also be overcome by adding 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. Solar-based chargers may be particularly attractive in off-grid areas. Recharge shops using solar panels have already sprung up in many rural areas. Individuals can also take advantage of solar energy through mobile connected devices with solar cells[17], small personal solar chargers and combined solar lamps and phone chargers (GSMA, 2011). Other innovative solutions include hand crank chargers, bicycles, a microturbine[18] or a shoe developed in Kenya which charges the phone while walking (Sawa, 2013).

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 3-3 for a definition of mobile broadband). Subscriptions are predicted to expand to 7.6 billion by 2019 (Ericsson, 2014).

[17] While solar powered mobile phones have already been on the market for some time, other connected devices are also being developed. For instance, the South African company Millbug has developed the solar-powered tablet which is set to go on sale for around ZAR1500 (just over EUR 100) (oAfrica, 2014). The Canadian company Wewi Telecommunications has released a solar-powered laptop on the Nigerian market which retails at less than NGN 100,000 (around EUR 470) (Adepoju, 2014).

[18] aquakin.com/de/wasserkraftwerke/microturbine-blue-freedom (accessed 8 February 2015)

Box 3-3: 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, para. 15, citing the 1999 First Broadband Deployment Report, para. 25).

For the purpose of this chapter, 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, 2011b). Ericsson uses a similar definition in its Mobility Reports[19]. 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 "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, p. 6).

Mobile broadband subscription rates in developing countries have grown from 0.8% in 2007 to 17% in 2013 with an annual growth rate of 66%, overtaking fixed broadband in 2011 which have largely stagnated.[20] 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. With just 11%, Africa trails furthest behind.

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, 2011a). LTE networks (also referred to as 3.9G) are only slowly being introduced in developing countries while 4G networks are still at an early stage of development (Ericsson, 2014). 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

[19] www.ericsson.com/mobility-report (accessed 12 September 2014)
[20] ITU statistics, www.itu.int/en/ITU-D/Statistics (accessed 9 September 2014)

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, 2011a). 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% of monthly per capita GNI in developed countries and 11-25% 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 US$20 per GB in Tanzania, Kenya and the Gambia (for low usage of up to 100 MB) to over US$100 per GB in Botswana, Mozambique, Zambia and South Africa (Schumann and 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 and 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 and 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[21]
- 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[22]
- the use of smartphones to set up a mesh network using the phones WiFi connections being trialled by the Flinders University in Adelaide, Australia[23]
- a Wireless Backhaul Technology (WiBack) being trialled by the German Fraunhofer Institute for Open Communication Systems (Fraunhofer FOKUS) 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)[24]

[21] www.google.com/loon (accessed 15 August 2013)
[22] brck.com (accessed 15 August 2013)
[23] www.servalproject.org (accessed 15 August 2013)
[24] net4dc.fokus.fraunhofer.de/en/projects/wiback.html (accessed 15 August 2013)

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.[25] In Kenya, 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.

Prospects for m-services

Agriculture-related m-services reviewed in this research mainly use SMS or voice-based systems (see Section 2.1 for examples). 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, using delivery modes such as video or interactive touchscreens. 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 3.1.3, these opportunities will need to be weighed against potential constraints and trade-offs such as network capacities, costs, battery power or usability.

Internet of Things

IoT technologies

A technology trend that is predicted to revolutionise 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, 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

[25] en.wikipedia.org/wiki/ForgetMeNot_Africa (accessed 18 August 2013)

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. First, 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. Second, the IoT can 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 and Machina Research, 2012). Cisco puts the figure even higher, estimating the number of internet-connected devices to reach 50 billion by 2020 (Evans, 2011). While mobile handsets make up the majority of these devices today, M2M devices, such as radio-frequency identification (RFID) tags, sensors or meters, are expected to become increasingly widespread. The GSMA and Machina Research (2012) 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) predicts 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.

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 et al., 2002).

Precision agriculture originated in the EU, US and Japan in the early 1980s, in part driven by the need to comply with environmental 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 et al., 2006; Mondal et al., 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 the absence of M2M strategies by 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 the agriculture sector in developing countries. 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 et al., 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.

- IoT technologies are also being used to track the movement of cattle. 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 (The Cattle Site, 2012). 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 et al., 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. In India, a GIS-based tool was developed to help villagers better prepare for drought (Kumar et al., 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 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 to manage micro-insurance schemes for crop and livestock producers, including *ACRE* which uses data from weather stations to trigger insurance pay-outs in case of severe weather events via mobile phones and the livestock insurance by the International Livestock Research Institute (ILRI) and others which calculates pay-outs for livestock losses using satellite data (i.e. the normalised differenced vegetation index or NDVI) to monitor forage scarcity.

Possible applications to facilitate *access to agricultural inputs* (e.g. seeds, fertiliser, water, electricity or labour) may be more limited. One example is the m-service *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.

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. 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. Similarly, the Syngenta Foundation's *Farmforce* tool employs 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).

Capitalising on networks and large user base

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

Data collection

Mobile devices can be used in varies ways to collect large amounts of data. 'Big data' has emerged as a buzzword to describe this trend, but the term is not clearly defined in the literature. Manyika et al. (2011) describe big data as "datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyse" (p. 1), 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.

The diversification of wireless technologies and the expansion of 4G networks are increasing the utility of mobile connected devices for data collection (Cisco, 2013). Smartphones are expected to be the main source of mobile data growth in the future. They already accounted for 92% of handset data traffic in 2012 although they only made up 16% of handsets in use globally (ibid). 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).

Mobile telecommunication data held by MNOs, for instance, can offer insights into people's movements, calling habits and social connection. Such data include traffic data (e.g. call or SMS volumes), service access detail records (e.g. time and duration of services used), movement and location variables, and device characteristics, customer details and tariff data (ITU, 2014). In development research, such data can be used e.g. in disaster management, diseases surveillance, transport planning or socio-economic analysis. Wesolowski et al. (2012), for example, used data from cell phone towers in Kenya to monitor human travel and thereby identify importation routes for malaria through movements of infected people.

The largest mobile telecommunication data set was released by the MNO Orange in 2015 which made available 2.5 billion anonymised records from Côte d'Ivoire and, in cooperation with the University of Leuven and the Massachusetts Institute of Technology, launched the *Date for Development* Challenge which asked the scientific community how big data could contribute to the development of an emerging country.[26] One submission, for instance, suggested 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 (Smith et al., 2013). A similar challenge was launched for Senegal in 2014 using anonymous mobile network data released by Sonatel and Orange.

In addition to analysing incidentally collected data from mobile operators, 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. Possible applications include geo-targeted links between agricultural suppliers and buyers, pest alerts or agricultural yield/shock predictions (Naef et al., 2014). Cloud-based services will facilitate the storage and analysis of such data, including combining data collected through

[26] www.d4d.orange.com (accessed 13 January 2015)

mobile devices with other data stored in public databases. Importantly, any initiatives to collect and analyse big data will need to bear in mind issues of personal privacy and commercial sensitivities around data access (Naef et al., 2014).

Large multinational companies such as Monsanto, John Deere and DuPont Pioneer are investing heavily in developing tools to make use of data in industrial agriculture, but smaller companies in developing countries are also following suit. *CropIn* in India, for instance, uses cloud and mobile technologies to collect and analyse data at the level of individual farms, clusters of farms, districts, states and the country. Useful data could also be obtained from 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.

Crowdsourcing

Information gathering 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 and González-Ladrón-de-Guevara, 2012). The Kenyan m-service *Ushahidi* is a prominent example of this approach. *Ushahidi* offers 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.[27] 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* (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.

[27] See https://wiki.ushahidi.com for an overview of deployments (accessed 24 January 2015)

- 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 et al., 2013).
- 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 fertiliser, from farmers using mobile data collection tools.

Such initiatives can at times be challenging to implement (de Carvalho et al., 2011). Lower income groups are often 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. 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.

Social networking and learning

ICTs are also facilitating social networking and learning. *Facebook*, for instance, probably the most well-known example of a social networking application, 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) finds 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 et al., 2013).

In addition to international applications, national and regional networking services 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 agriculture sector which are using ICTs to support social learning among farmers. *AgTube*, for instance, is a social media platform for rural people in developing countries where farmers can upload and discuss videos of farming practices. 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. Other examples include the *Lifelong Learning for Farmers* initiative targeted at livestock producers in India and *Sauti ya wakulima* in Tanzania (see Section 2.1.1). As elaborated above, *PRAM-KSN* facilitates social learning through information exchange and collective problem solving among extension workers via the internet.

3.1.3 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)
2. Big Leap (significant advances in the technology trends).

Table 3-1 summarises 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 summarised in the previous section. The focus is on the utility of and implications for smallholder farmers as well as other farmers in developing countries.

Table 3-1: Two scenarios for the possible evolution of the technology trends

		Status Quo	Big Leap
Diverse Devices	**Mobile interface**	Feature phones, some higher-end devices	High-end feature phones, smartphones, tablets
	Delivery technologies	Voice, SMS, USSD, WAP, embedded apps, some web and platform apps	Mainly web-based services
	Cloud/web-based services	Some, but apps mainly stored on devices	Widely used
Internet of Things	**IoT services**	Some within specific applications	Interconnected devices
	Decision support tools	Some within specific applications	Complex tools operating across applications
Capitalising on networks	**Big data**	Incidentally collected data, some through projects	Continuous collection of diverse data
	Crowdsourcing	Some within specific projects	Large network of connected users
	Results sharing	Some project data shared	Results widely accessible
	Social learning	Some within specific projects	Large network of connected users

Possible scenarios

Scenario 1: Status quo

Outcomes of technology trends

Diverse devices
Feature phones are the most used mobile phone. 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 users) or platform and web-based applications (through intermediaries). 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 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 is required, thus limiting the utility of these services by illiterate users. 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 low-income users to purchase. Tablets are often not affordable

by individuals 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 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. 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. 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 customers 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 or 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.

Assumptions

Usability

Smartphones and tablets are better suited for sophisticated services and web-based applications. However, the devices are also more complex to use, at least initially, because of the novel interface. 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. 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 intermediaries (as in the example of the CKW initiative in Uganda) or by combining different ICTs (such as mobile devices and radio).

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, users 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 viable.

Innovation environment

Financing for local service providers is available from a range of investors, including local investors and investors from emerging economies. While development and delivery of m-services 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). 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.

Implications for m-service provision to farmers

The two scenarios would have different implications for the provision of m-services to facilitate agricultural technology adoption among farmers. Using the categorisation of m-services elaborated in Chapter 2, the following implications could be envisaged (see Table 3-2 for a summary of the big leap scenario).

Table 3-2: Potential impact of the 'Big Leap' scenario on the provision of agricultural m-services

	Big Leap	Impacts on ag m-services
Diverse Devices	High-end feature phones, smartphones, tablets mainly using web-based services	Delivery of complex information through more sophisticated interfaces
		Interactive training
		M-payments integrated with banking services and insurance schemes
		Virtual markets using sophisticated applications e.g. images, ratings, m-payments
Internet of Things	Interconnected devices using complex decision-support tools operating across applications	Data collection for site-specific management of fields
		Remotely managed insurance schemes for smallholders
		Supply chain management to source from smallholder farmers
		Quality assurance in virtual markets
Capitalising on networks	Continuous collection and sharing of diverse data through large networks of connected users	Crowdsourcing of information for decision-making, e.g. output and input prices, buyers, weather info
		Analysis of collected info for longer-term planning e.g. price trends, weather patterns
		Virtual market data used to plan infrastructure investments
		Social learning across national and international networks

Information and learning

<u>Scenario 1: Status Quo</u>
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 confined projects. Publicly available social networks are too general to lend themselves to issue-specific information exchange and learning.

<u>Scenario 2: Big Leap</u>
Higher-tech devices and faster networks allow m-service 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 interfaces increase the reach of m-services to illiterate farmers although training is still needed to familiarise them with the new features of higher-tech devices. 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. Developers' focus on web-based services limits the availability of m-services for low-tech phones, thus disadvantaging some 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

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

<u>Scenario 2: Big leap</u>
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

<u>Scenario 1: Status Quo</u>
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 technologies 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 crowdsourced 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. Farmers are able to access these sophisticated services through high-tech devices. The data collected through these virtual transactions allows for more strategic investments into transportation routes and storage facilities.´

3.2 M-Services in Kenya's Agriculture Sector

Kenya has emerged as a frontrunner in the development of m-services in Sub-Saharan Africa. The mobile payment system *M-Pesa* is one of the most successful mobile banking systems in the developing world. M-services are also being offered in other sectors, such as education, health and entertainment. In the area of agriculture, farmers have access to a range of m-services, many of which are provided by local companies, although most services remain at a small scale. The local technology scene owes its growth in part to the innovation environment fostered by local and international developers, entrepreneurs and investors, as well as national government policies. An increasingly well-connected customer base and improving infrastructure are also helping entrepreneurs to market their services.

3.2.1 Kenya's ICT Ecosystem for Local Entrepreneurs

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

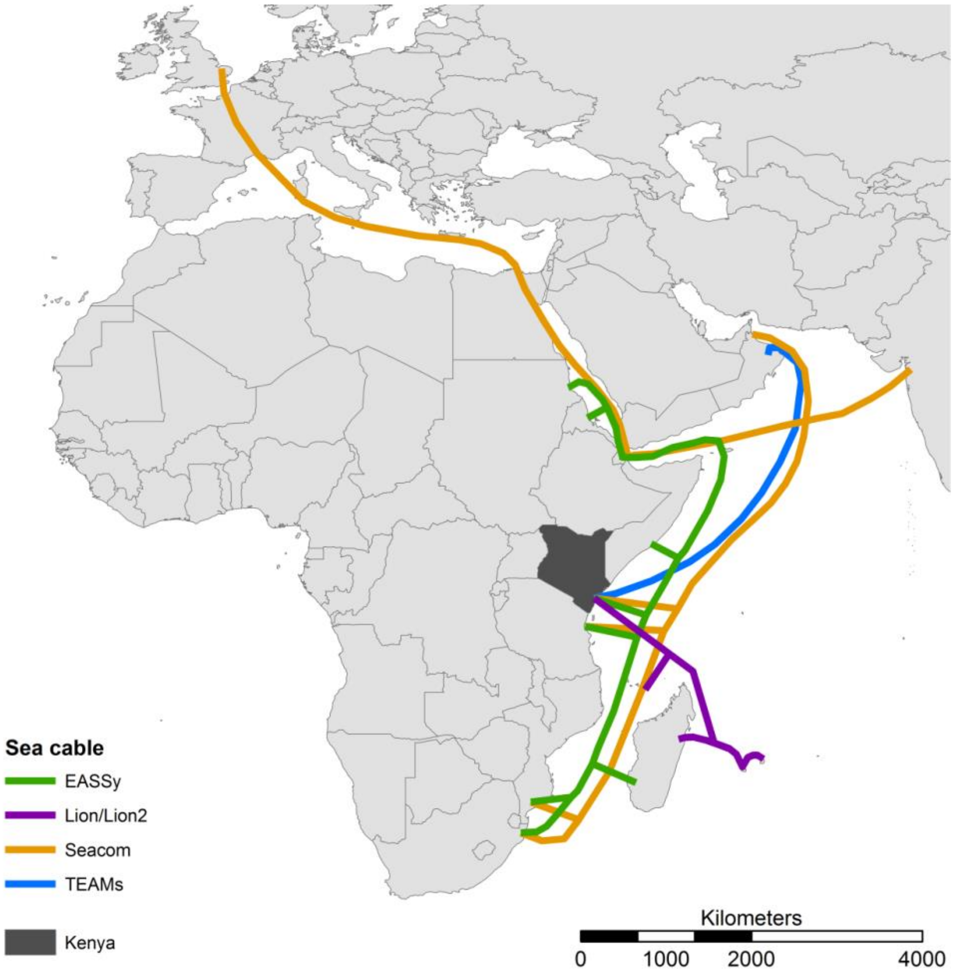
Kenya's growing ICT ecosystem is making the country an increasingly attractive place for local entrepreneurs to develop and deploy m-services. The first sea cable to link Kenya to the broader internet came online in July 2009, thereby offering a faster and cheaper alternative to satellite connections (McCarthy, 2009). Since then, three additional sea cables have been connected to landing points in Mombasa (Table 3-3 and Map 3-1). Another three cables are planned (Mbuvi, 2013). Terrestrial fibre 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 fibre optic backbone infrastructure (Wahito, 2012). As elaborated below, the government has supported infrastructure expansion through various regulatory measures and financing.

Table 3-3: Sea cables linking Kenya to other countries

	Partners	Landing points	System length	Design capacity	Date of first use
SEACOM	Seacom Ltd (76.56% African ownership)	France, Djibouti, Kenya, Tanzania, Mozambique, South Africa, India	17,000 km	4.2 Tb/s	July 2009
The East African Marine System (TEAMS)	Government of Kenya; Kenyan private investors; Etisalat	Kenya, United Arab Emirates	5,000 km	40 Gb/s (upgradeable to 640 Gb/s)	October 2009
East African Submarine Cable System (EASSy)	West Indian Ocean Cable Company (incl. Telkom Kenya Ltd.) as the largest shareholder; other private investors	Sudan, Djibouti, Somalia, Kenya, Comoros, Tanzania, Madagascar, Mozambique, South Africa	10,000 km	4.72 Tb/s	July 2010
Lower Indian Ocean Network (LION2)	Telkom Kenya Ltd; other France-Telecom-Orange subsidiaries; private carriers	Mayotte, Kenya (extension of LION to Reunion, Mauritius and Madagascar)	2,700 km (extension of LION)	I.28 Tb/s	April 2012

Sources: www.seacom.mu, www.teams.co.ke, www.eassy.org (accessed 13 March 2012); France Telecom-Orange (2012); Wikipedia (2012a, 2012b)

Map 3-1: 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 3-4 years.[28] 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 are also starting to link up with or invest in their own innovation spaces in Kenya. Intel, for instance, entered into an agreement with the iHub to foster local mobile app development while Nokia and IBM have opened research centres in Nairobi, their first such centres in Africa.

[28] Key informant interview, May 2012

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 ideas and talents in the hope of returns when selling their stakes to a larger investor once the business has matured.[29] The Savannah Fund, for instance, was launched in mid-2012 as a seed capital fund specialising in US$25,000-US$500,000 investments in early stage high growth technology (web and mobile) start-ups in sub-Saharan Africa.[30] Financing for Kenyan start-ups is also available through numerous competitions, such as Pivot East, IPO48, Apps4Africa, Google Apps Developer Challenge or the Orange African Social Venture Prize in which developers can win seed funding of US$ 10,000 to 25,000. 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.[31] Training opportunities are expanding, notably through eMobilis, the first Mobile Technology Training Academy in Sub-Saharan Africa, which 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*, *Kopo Kopo*[32] or *M-Farm*.[33] 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 been actively promoted by the Kenyan government. The sector has emerged as a key driver of economic growth over the past decade, showing an annual growth rate of around 20% and adding 0.9% to annual Gross Domestic Product (GDP) growth since 2000 (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 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 helped to promote 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[34] and without restrictions on the number of operators allowed to build and

[29] Key informant interview, May 2012
[30] www.savannah.vc (accessed 6 June 2012)
[31] Key informant interview, May 2012
[32] A platform to enable small and medium businesses to accept mobile payments and build relationships with their customers (http://kopokopo.com, accessed 14 April 2013).
[33] Key informant interview, May 2012
[34] 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 three years of receiving the license.

operate ICT infrastructure. Other measures included investments in submarine[35] and terrestrial fibre optic cables, the removal of a value added tax for mobile handsets, support for the development of the internet exchange point in Nairobi[36], sharing of the state-owned electricity company's infrastructure and reduction in the cost of calling between different mobile networks[37]. 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.

The government is also supporting the development of Konza Technology City[38] 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 first phase of Konza Technology City is set to be completed by 2018. The government also adopted a National Broadband Strategy to establish faster and more reliable broadband connections around the country (Okutoyi, 2012).

M-Pesa

M-service developers have also benefited from the success of the mobile banking service *M-Pesa* (see Section 3.2.2). Through its widespread adoption, *M-Pesa* has helped to prepare the ground for m-services in Kenya, familiarising many Kenyans with the use of their mobile phone for non-call related services. For instance, *M-Pesa* has been credited for the 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, 2012b). *M-Pesa* (and other m-payment systems) also provides supporting services for other 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 m-services is growing rapidly, not least driven by Kenya's young and increasingly educated population. Almost 40% of the economically active population was

[35] E.g. the government funded 85% of the TEAMS sea cable and later sold 65% of their stake to Kenyan operators.

[36] Internet exchange points (IXPs) enable internet players (including internet service providers, backbone providers and content providers) to exchange Internet traffic between their networks. In the absence of IXPs, operators of use international connections to exchange domestic traffic which increases costs and lowers service quality. The establishment of the Nairobi IXP in 2000 has reduced latency in the network, significantly cut costs of international transit and encouraged local content provision (Kende and Hurpy, 2012).

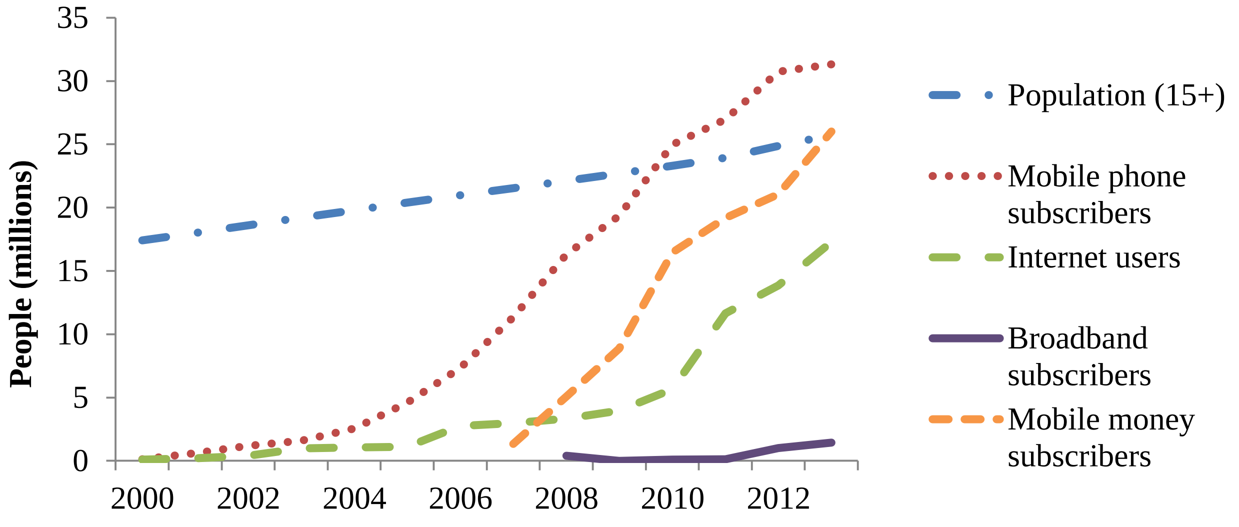
[37] In August 2010, the Kenyan regulator reduced the mobile termination rate (i.e. the rate charged by one mobile operator e.g. T-Mobile to another e.g. Orange when customers call from another network) from KSh 4.42 per minute to KSh 2.21. This reduction has contributed a 70% increase in network-to-network calls in three months compared to a 3% increase in calls within networks (CCK, 2011)

[38] www.konzacity.go.ke (accessed 13 Janaury 2015)

below the age of 30 in 2012 (ILO, 2011). School enrolment rates have been improving. By 2009, 50% of children in their age group were enrolled in secondary school, up from a third in 2000.[39] The youth are tech-savvy and interested, exemplified by the fact that Kenyans are the second most prolific tweeters in Africa after South Africa.[40] 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[41]) thanks to a growing network of fibre 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.[42] In 2010, the number of mobile phone subscribers for the first time overtook the number of people above the age of 15 (Figure 3-4). These rates compare well to the regional average of 75 per 100 across Africa and 95 per 100 in developing countries in 2013.[43] In 2013 the number of mobile money subscribers also for the first time slightly exceeded the number of above 15-year olds.

Figure 3-4: Mobile phone, mobile money and internet penetration in Kenya (2000-2013)



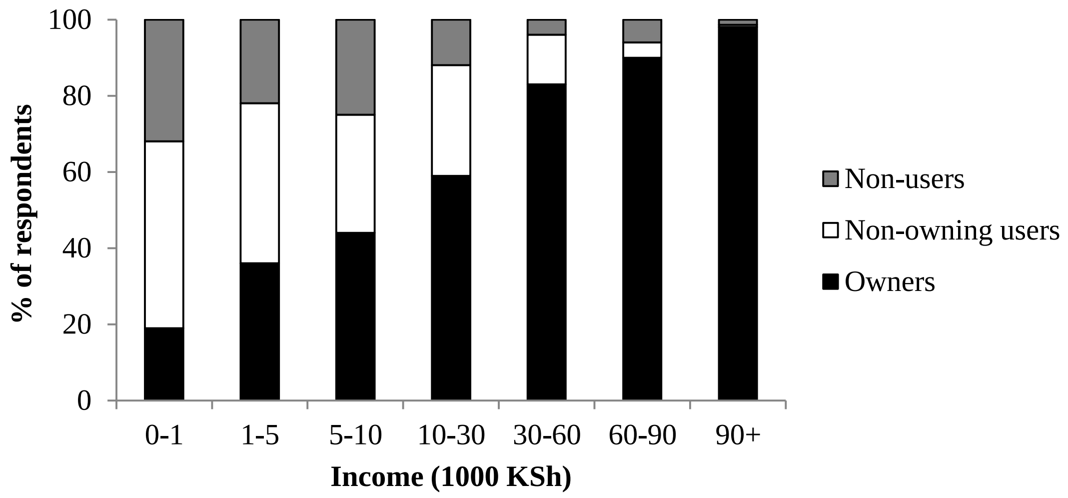
Note: The number of internet users was calculated by multiplying the share of the population using the internet (ITU) with the population (World Bank).
Data sources: ITU (mobile phone subscribers, share of population using the internet), World Bank (population), CBK (mobile money subscribers) (accessed 22 January 2015)

As already outlined in Box 2-5, subscription rates only provide a general indication of mobile phone access in a country. The GSMA believes unique subscriptions rates in Kenya to be considerably lower than total subscription rates at around 37% (Makau, 2012).

39 World Bank, data.worldbank.org (accessed 25 January 2012)
40 According to a survey carried out in the last quarter of 2011 (Portland Communications, 2012).
41 Waema, Adeya, & Ndung'u, (2010)
42 CA statistics, ca.go.ke/index.php/statistics (accessed 9 September 2014)
43 ITU statistics, www.itu.int/en/ITU-D/Statistics (accessed 9 September 2014)

Nevertheless, access to mobile phones is common in Kenya through the sharing of phones. One nationally representative survey observes that 85% of respondents used a mobile phone although only 44% owned a phone in 2009 (Wesolowski et al., 2012a). Phone sharing was particularly prevalent among low income groups (Figure 3-5) and in rural areas (even among higher income groups). Similarly, a survey of Kenyan farmers finds that only around a third owned a mobile phone, but 84% had used one (Okello et al. 2010).

Figure 3-5: Phone ownership and usage by income groups in Kenya



Data source: Wesolowski et al. (2012)

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 (CCK, 2013). Internet usage began increasing significantly in 2010 (Figure 3-4). While only around a third of Kenyans is estimated to use the internet, this share is almost three times higher than the African average (32% compared to 12% in 2012) and one of the highest on the continent.[44] 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 access 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).

… 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

[44] ITU statistics, www.itu.int/en/ITU-D/Statistics (accessed 15 July 2013)

the more senior established developers. [45] 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 recognising 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 is also needed. 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.[46] As a result, m-services risk turning into technology solutions, rather than solutions that address a particular demand.[47] This problem is not restricted to Kenyan developers, however. Ken Banks, the founder of *FrontlineSMS*, points out that 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 remains 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.[48] 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.[49] 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.[50]

Moreover, while the IT infrastructure is fairly advanced by regional standards, it continues to face problems. Overall, the share of the population using the internet is still low at less than a third in 2012 (Figure 3-4) 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

[45] Key informant interview, May 2012
[46] 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 $1,000 and 13% between $1,001 and $5,000 per app per month, while 25% will not generate any income at all (VisionMobile, 2012).
[47] Key informant interview, May 2012
[48] Key informant interview, May 2012
[49] Paul Kukubo, Chief Executive Officer, Kenya ICT Board @ Pivot East, 5 June 2012.
[50] Benjamin Matranga, Investment Officer, Soros Economic Development Fund @ Pivot East, 5 June 2012.

Nairobi. In addition, while the liberalisation 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 fibre optic cables in wealthy neighbourhoods (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 1 billion target in its first year 2013/1014 (ibid). The main challenges include high operational costs due to limited access to electricity, roads and infrastructure security, low population densities and high licence and spectrum fees coupled with unclear 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 governments new broadband strategy. Thus, while urban rates are supposed to reach 40 Mbps by 2017 (compared e.g. to an average speed of around 5 Mbps in Nairobi, Ookla 2013), the target for rural areas is only 5 Mbps (Okutoyi, 2012).

3.2.2 M-services for Kenyan Farmers

Kenya's agriculture sector is dominated by semi-subsistence, low-input and low-productivity farmers (Jayne et al., 2003b). Agricultural holdings tend to be small at 2.4 acres on average (KNBS, 2006a).[51] 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 2009-2011) include sorghum, tea, cow peas, coffee, wheat, pigeon peas, potatoes and millet.[52] Sugarcane is the main crop in terms of production volume followed by maize, potatoes and bananas.

Table 3-4: Basic facts about Kenya's agriculture sector

Land area	56,914		In 2009
Agricultural area	27,350	Share of land area: 48%	In 2009
Agricultural area (irrigated)	10.1	Share of agricultural area: 0.04%	In 2009

Note: Areas in 1000 ha
Source: FAO Stat, faostat.fao.org (accessed 7 January 2013)

Various m-services are already offered to Kenyan farmers (see Table 3-5, excluding financial services, as of June 2013). Most of these services are delivered 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'*

[51] "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, 2006a, p. 159)
[52] Data on production area and volumes: FAOStat, faostat.fao.org (accessed 28 February 2013)

Information Service, *Maize Variety SMS Service*) or international organisations (*Sokopepe*, *E-Farming*, *index-based livestock insurance*, *SALI*), and these are often also implemented in partnership with the private sector.

Service providers generally recognise that mobile phones will only ever be part of a broader solution. One m-service provider points out, "farming is done in the dirt, not on a mobile phone".[53] She notes that many ecological challenges remain that cannot be addressed through the mobile phone, such as drought and pests, and that care must be taken to ensure that the mobile buzz does not overshadow other types of solutions. Similarly, another provider stresses that they do not "attribute everything that happened to a farmer to this particular information service through the mobile phone. The farmer is exposed to so many different information sources – through the radio, through the neighbours, market sellers. The mobile phone is just a drop in the ocean."[54]

The remaining section outlines Kenyan farmers' access to information and learning, financial services, agricultural inputs and output markets in line with the categories developed in Chapter 2. For each category, relevant m-services already available in Kenya are identified. 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.

Table 3-5: Examples of m-services offered to Kenyan farmers

	Service provided	Technology	Implementing partners
M-Farm	Daily crop price information, selling of produce, purchasing of inputs (on hold) Start date: October 2010	Mobiles (SMS-searchable database for prices, SMS message to sell), website (prices, virtual market)	*M-Farm* Ltd (Kenyan company)
Kenya Agricultural Commodity Exchange (KACE)	Weekly crop price information, *Soko Hewani* to sell produce through radio auctions Start date: 1997 (company)	Mobiles (USSD) for prices, website (prices), radio programme accessed through Market Call Centres (selling)	Kenya Agricultural Commodity Exchange (Kenyan company)
SokoPepe	Agricultural information (e.g. climate changes, product prices, services for farmers, agricultural methods), selling of produce Start date: October 2010	Mobiles (SMS-searchable database for prices, SMS sent to registered users, SMS message to sell, m-payments), website (prices, virtual market), Knowledge centres with ICT facilities	Arid Lands Information Network
SokoShambani	Mobile trading platform to link potato farmers and restaurants	Mobiles (SMS to Twitter shortcode)	mFarmer Kenya (umbrella agricultural venture of ZEVAN enterprise)
ArifuMkulima	Agricultural information (e.g. weather, diseases, calendar alerts, farm inputs, financial advice, agrovets)	Mobiles (SMS sent to registered users), internet	mFarmer Kenya (umbrella agricultural venture of ZEVAN enterprise)

[53] Key informant interview, May 2012
[54] Key informant interview, May 2012

	Service provided	Technology	Implementing partners
kuza Doctor	Agricultural production information for 10 crops (20 crops planned) in English & Swahili (Luganda planned) Start date: August 2011	Mobiles (SMS sent to registered users, USSD planned)	Backpack Farm (Kenyan company)
M-Kilimo	Agricultural information (e.g. land preparation, planting, pest management, harvesting, post-harvest and marketing)) Date: 2009 – 2011	Telephone (helpline)	KenCall (Kenyan company) and GSM Association
National Farmers' Information Service (NAFIS)	Agricultural information (e.g. crops, livestock, market prices on inputs and outputs, other info) Start date: April 2008	Telephone (IVR in Kiswahili and English), website	NALEP (MoA, MoLD), Teknobyte (Kenyan co), Speechnet, Popote Wireless (Kenyan co), University of Nairobi, AIRC (MoA); pilot with Uppsala Uni, Outside Echo (UK)
E-Farming55	Agricultural information (e.g. soils, fertiliser application, agronomy, markets or pesticide use) Start date: 2012	Mobiles (SMS)	African Soil Information Service, African Soil Health Consortium, FibreLink Communications
Maize Variety SMS Service	Information on the most suitable maize variety to grow in the division	Mobiles (SMS-searchable database)	Two separate services run by Kenya Plant Health Inspectorate Service and Kenya Seed Company
Sustainable Agriculture and Livelihoods Initiative (SALI)[56]	Weather and marketing information Start date: 2011	Mobiles (SMS)	Christian Aid in cooperation with the Kenyan Meteorological Department, Traidcraft
iCow	Livestock production information (e.g. info about local services, record keeping, best practice, cow calendar) and virtual livestock market Start date: June 2011	Mobiles (SMS sent to registered users), website	Green Dream Tech (Kenyan company)
FrontlineSMS Radio	e.g. The Organic Farmer, *Pur Mariek* (farm wisely) on Radio Nam Lolwe Agricultural information on the radio in response to farmers' questions	Radio, Mobiles (SMS enquiries), FronlineSMS software to manage incoming SMS	FrontlineSMS in cooperation with local radio stations

[55] Okoth (2013)
[56] Christian Aid (n.d.)

	Service provided	Technology	Implementing partners
FarmerVoice Radio	Agricultural information Start date: July 2009	Radio, Mobiles (SMS enquiries and calls to contact radio station)	Kenya Broadcasting Corporation, Kenyatta University, JKUAT, FIT Resources, Kenya National Federation of Agricultural Producers, local radio stations and others[57]
ACRE (formerly Kilimo Salama)	Insurance to protect crops against drought or flood Start date: 2009	Weather stations linked to central system, Mobiles (SMS confirmation for premiums, pay-out through *M-Pesa*)	Syngenta Foundation, Safaricom, UAP Insurance
Index-based livestock insurance	Insurance against drought-related livestock mortality Start date: January 2010	Scanner-based mobile phones to register insurance contracts, satellite and historical data to assess mortality rates	International Livestock Research Institute and with technical and implementing partners[58]
Agrimanagr	Supply chain management Start date: 2010	Mobiles (to track deliveries, info sent to mobility network)	Virtual City (Kenyan company)
farmforce	Supply chain management Start date: 2012	Mobiles (SMS, apps), PC	Syngenta Foundation

Access to information and learning

Kenya's smallholder farmers tend to rely mainly on local sources of knowledge, including family, friends, markets or community-based organisations (Rees et al., 2000). The importance of other sources can vary depending on the area (ibid). In Homa Bay district, for instance, which is located near the study sites for this research, faith-based organisations and NGOs play an important though generally localised role, while in Kiambu district near Nairobi agribusinesses were found to be more relevant.

In terms of organised extension services, Muyanga and Jayne (2006) identify two main types – government extension services and commodity-based systems run by companies or cooperatives. Many of these services are provided through farmers' groups. Government extension services are generally seen as a valuable source of information (Rees et al., 2000), but also face significant challenges. Rural services tend to be under-funded and under-staffed. In Nyanza province, for instance, where the two study sites are located, one extension officer is responsible for around 5,000 farmers.[59] Extension services are particularly limited for poor and remote producers of low-value crops with little marketable surplus (Muyanga and Jayne, 2006).

Most of the services listed above focus on information provision. Several services deliver production-related information for crops (*ArifuMkulima*, *Sokopepe*, *kuza doctor*, *M-*

[57] For a full list, see www.farmervoice.org/Consortium#Kenya_partners (accessed 13 January 2012)
[58] livestockinsurance.wordpress.com/ibli-marsabit-pilot-2 (accessed 13 January 2012)
[59] Key informant interview, May 2012

Kilimo, *NAFIS*, *E-Farming*, *Maize Variety SMS Service*, *SALI*) or livestock (*iCow*) via SMS, phone calls and/or websites. Several radio stations also offer interactive programmes in 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). The impact of these services has not been assessed in any detail. A small survey of *iCow* users finds that 82% of farmers were still using the service seven months later (iCow, 2010). 42% of farmers thought their income had increased, with just over half attributing income increases to increased milk yield.

Access to financial services

Data from two surveys carried out in 2006 and 2009 as part of the Financial Sector Deepening Kenya programme by the government of Kenya, the World Bank and various donors[60] provides comprehensive data on access to financial services in Kenya. While access to some financial services has improved considerably in the last few years (notably transmission services), access to other services is less common, especially in rural areas. Of particular interest to farmers are transmission services (e.g. to pay for inputs, sell outputs or receive off-farm income), credit (e.g. to finance inputs), banking (e.g. to sell outputs or earn interest on savings) and insurance (e.g. to insure crops against severe weather events).

Access to transmission services is common even in rural areas, owing to the widespread availability of mobile payment services. Since its launch in 2007, Safaricom's *M-Pesa* has dominated the m-payment market in Kenya, in particular regarding its share of m-money transfers (Table 3-6). Prior to 2007, economic transactions were mainly carried out in cash or barter (Suri et al., 2012). Money was commonly sent in person due to the low densities of bank branches, ATMs and Western Union agents. Thus, one of the most immediate needs addressed by *M-Pesa* was the transfer of remittances, resulting in a rapid expansion of *M-Pesa* agents both in urban and rural areas. At the time of its launch, *M-Pesa* also benefited from Safaricom's high market share which offered access to a large potential customer base.

By the end of 2013, *M-Pesa* had expanded to over 18 million registered customers (11.6 million active) with close to 80,000 agent outlets across the country (Safaricom, 2013). As Suri et al. (2012) note, "[m]obile money in Kenya has achieved take-up rates far superior to those of Green Revolution technologies in South Asia which are often cited as technology adoption success stories" (p. 10258). Other providers have since entered the m-payment market, but they are still struggling to expand their share of m-money customers, transfers and agents. While Airtel has made most progress in expanding its customer base, the share of transfers remains minimal.

[60] See www.fsdkenya.org (accessed 18 September 2014)

Table 3-6: Mobile money providers in Kenya

Provider	Transfers (KSh bn in Dec.2011)	Share of transfers	M-money customers as at 31/12/2011 (million)	Share of customers	Agents	Share of agents
Safaricom (*M-Pesa*)	116.6	98.5	15.21	79.2	35,350	70
Tangaza Peza	1.31	1.11	0.07	0.4	1,745	3.5
Airtel (*airtel Money*)	0.42	0.35	3.16	16.5	3,161	6.3
Yu (*yuCash*)	0.02	0.02	0.52	2.7	5,579	11.1
Orange (*Iko Pesa*)	0.02	0.02	0.13	0.7	3,609	7.2
Mobikash	0.004	0.00	0.11	0.6	1,027	2.0

Data source: Central Bank of Kenya cited in Mugwe and Okuttah (2012)

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 finds 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). As elaborated in Section 2.2.2, most of the m-payments were used for non-agricultural purposes. Factors influencing the propensity of farmers to transfer money through their mobile phone included the level of commercialisation, distance to banks, education levels and capital endowments.

With regard to other financial services, access to formal services is low, in particular in rural areas. Only 35% of rural respondents in the Finaccess survey had access to formal services, e.g. banks, insurance, cooperative societies or micro-finance institutions, compared to almost two thirds in urban areas (Figure 3-6). The remainder used informal services or did not have access to any services. Access had improved since the previous survey in 2006, but less so in rural areas where use of formal services increased only by around 11% compared to 30% in urban areas (FSD Kenya and CBK, 2009).

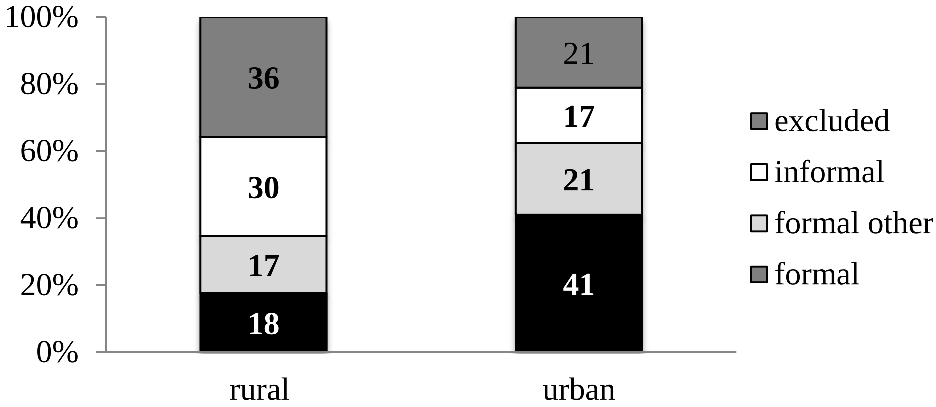
Access to credit was only slightly lower in rural than urban areas in 2009 (37% compared to 41%), but rural users tend to rely more on informal sources of credit, such as shops, suppliers or family members (FSD Kenya and CBK, 2009). In most cases, rural households do not use the credit for agricultural purposes. A survey carried out in 2005 finds that only 6.8% of rural households borrow money to purchase agricultural inputs and to a lesser extent agricultural machinery (KNBS, 2006a). Instead, credit mainly goes towards paying for subsistence needs (39%), medical costs (17%) and school fees (16%). A study of smallholder farmers in Kenya also concludes that usually farmers can only access inputs on credit if they are part of an integrated cash crop program (Jayne et al., 2003a). Farmers often find it difficult to obtain credit for crop production because they lack collaterals[61] and because they are unable to make regular repayments due to the seasonality of agriculture incomes[62].

Mobile payment providers have recently begun collaborating with local banks to also provide other banking services. *Iko Pesa* (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. Data on the uptake of these services is not available.

[61] Key informant interview, May 2012.
[62] Key informant interview, May 2012.

Only a small share of rural Kenyans (4.8%) had formal insurance in 2009, with little improvement since the previous survey in 2006 (3.6%). Access to insurance in urban areas is also low, but better (14.1% in 2009). The majority of insurance products covered medical and social security costs. A common (informal) insurance is membership in welfare groups (53% of respondents) although mainly to cover emergency costs such as funerals or medical bills. Two mobile phone-assisted insurance schemes are available in Kenya, both of which insure farmers against extreme weather events that might affect livestock (ILRI's index-based livestock insurance) or crops (*ACRE*), but their reach is still limited.

Figure 3-6: Access to financial services in rural and urban areas of Kenya (2009)



Formal – use a bank, Postbank or insurance product
Formal other – do not use any formal product, but use services from nonbank financial institutions such as SACCOs (Savings and Credit Cooperative Societies) and MFIs (Micro-finance Institutions)
Informal – do not use any formal/formal other products but use informal financial service providers such as ASCAs, RoSCAs and groups/individuals other than family/friends
Excluded – use no formal/formal other or informal financial services
Data source: FSD Kenya and CBK (2009)

Access to agricultural inputs

With the adoption of the Strategy for Revitalising Agriculture in 2004, the government has stepped up efforts to promote the use of modern agricultural technologies among Kenyan farmers, in particular improved seeds and fertiliser which are distributed through a network of agro-dealers. While various support programmes have been implemented to assist agro-dealers, the outcomes of these programmes appear to be mixed. Odame and Muange (2011) find the distribution of agro-dealers to be uneven, as larger agro-dealers and those in high-rainfall areas had benefited more from the support programmes. The focus tends to be on maize which they argue has disadvantaged in particular farmers in low-rainfall areas who rely on a more diverse range of crops. Moreover, financial constraints mean that many agro-dealers are unable to stock sufficient inputs to service all farmers in the peak season.

Most farmers continue to re-use seeds from the previous harvest or obtain their seeds through the informal seed system. A rural household survey carried out by Ayieko and Tschirley (2006) shows that just 18% of seeds were purchased on the formal market while almost a two thirds were retained and 19% bought informally. Most households tend to use all three types of seed sources. Reasons for the low uptake of certified seeds for most crops include the weak input supply system, lack of credit to purchase the seeds, small land sizes and the lack of breeding programs for many crops (ibid).

Maize – the primary staple crop in Kenya – is one of the few crops that are predominantly sourced through the formal seed system, mainly from public and private seed companies (Ayieko and Tschirley, 2006).[63] Two thirds of maize seeds are estimated to be supplied through the formal system while the remainder is obtained from the farm (32%) or community-based schemes (2%). However, despite the widespread adoption of certified maize seeds, yields overall have not improved since the 1980s, fluctuating around 1700 kg/ha over the last three decades.[64]

Fertiliser use is fairly widespread in Kenya, in part due to a liberalisation of the fertiliser market in the 1990s which attracted a large number of private actors into the sector (Jayne et al., 2003a). By 2005/06, 69% of parcels were using fertiliser, although use rates differed quite considerably between districts from 6% to 100% (KNBS, 2006a). Among smallholder farmers, a survey finds that use of fertiliser increased between 1997 and 2007, but application rates had largely stagnated (Ariga et al., 2008). In 2010, 30% of smallholders did not use fertiliser, mainly because they could not afford it (51%) or because they did not see the need to use it (33%) (Olwande, 2012).

Use of irrigation in Kenyan agriculture is very low. Only 6% of parcels[65] were under irrigation in 2005/06, including in areas where crop intensity is high (see Map 3-2 and Map 3-3). Experiences from other countries show that the availability and control of water resources are often among the most important factors explaining differences in patterns of agricultural technology adoption (as reviewed e.g. in Feder & Umali, 1993; Barker et al., 1985). Indeed, Odame and Muange (2011) note that concerns over unreliable rainfall are often the main deterrent for Kenyan farmers in low-rainfall areas to using inputs rather than lack of access to inputs.

None of the m-services reviewed in this research focused on input provision. *M-Farm* initially offered a service for collective sourcing of fertiliser, but put the service on hold due to liquidity constraints among farmers (see Section 4.3.1). *NAFIS* and *ArifuMkulima* provide price information for inputs, but it is unclear to what extent this function is operational.

Access to output markets

Kenya's smallholder farmers struggle to take advantage of market opportunities which could provide necessary income and incentives to invest in agricultural technologies. The bulk of the sales often occur in a short period of the year when prices are low and many farmers are in fact net buyers of the crops they produce. Renkow et al. (2004), for instance, find that 83% of maize sales occur during the two months of harvest. Similarly, Stephens and Barrett (2011) note that close to two thirds of the 30% of smallholder farmers in Western Kenya who were net maize sellers in the harvest season became net maize buyers a few months later. The authors attribute this pattern to limited access to liquidity (credit or off-farm income) which forces households to sell even when prices are low.

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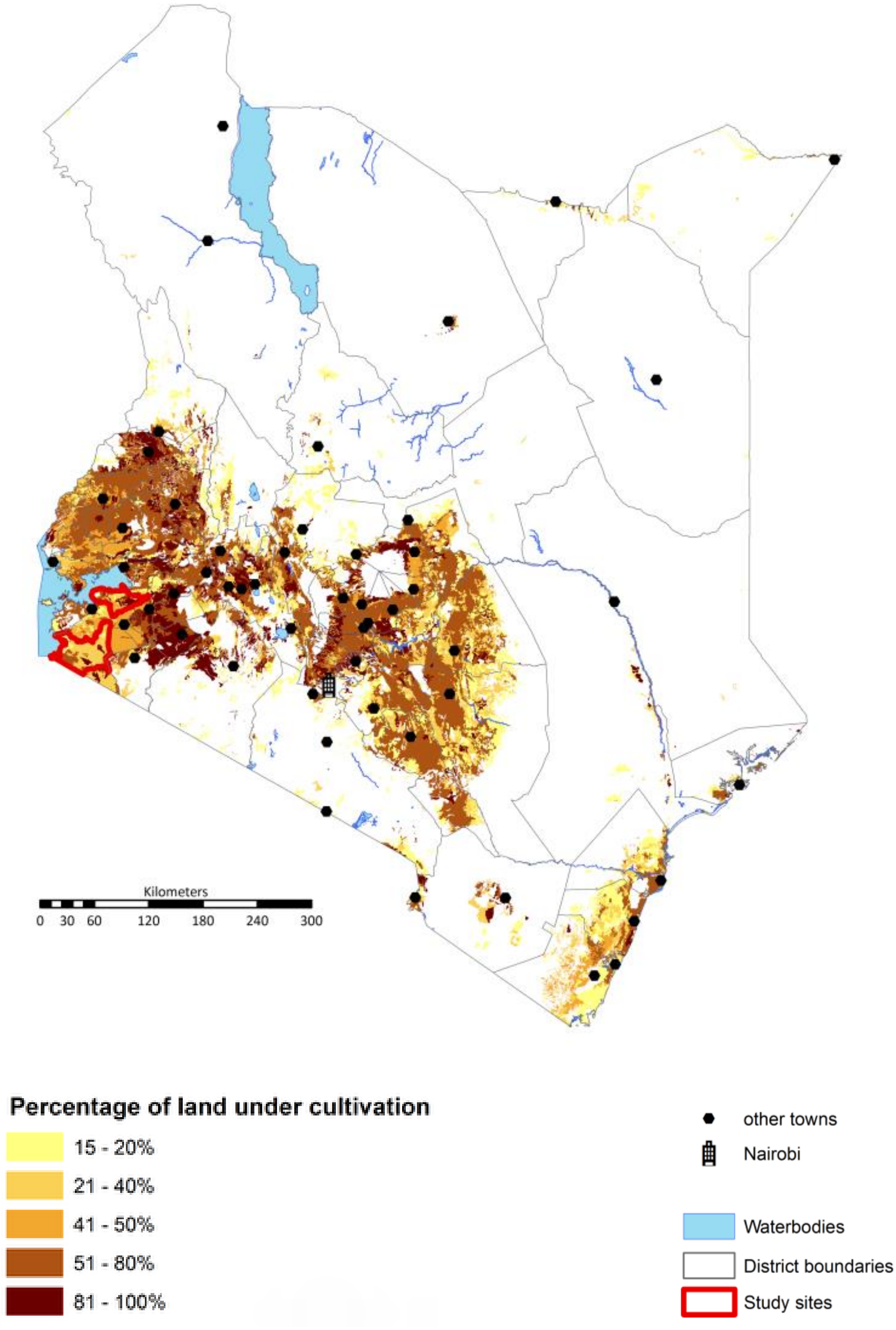
[63] Other crops include rice and industrial crops (sugarcane, tea and coffee).

[64] Yields ranged from 1294 kg/ha to 2071 kg/ha, with an average of 1685 kg/ha between 1981 and 2011. The trend during that time showed an overall decline in yields. Source: FAOStat, accessed 13 February 2013.

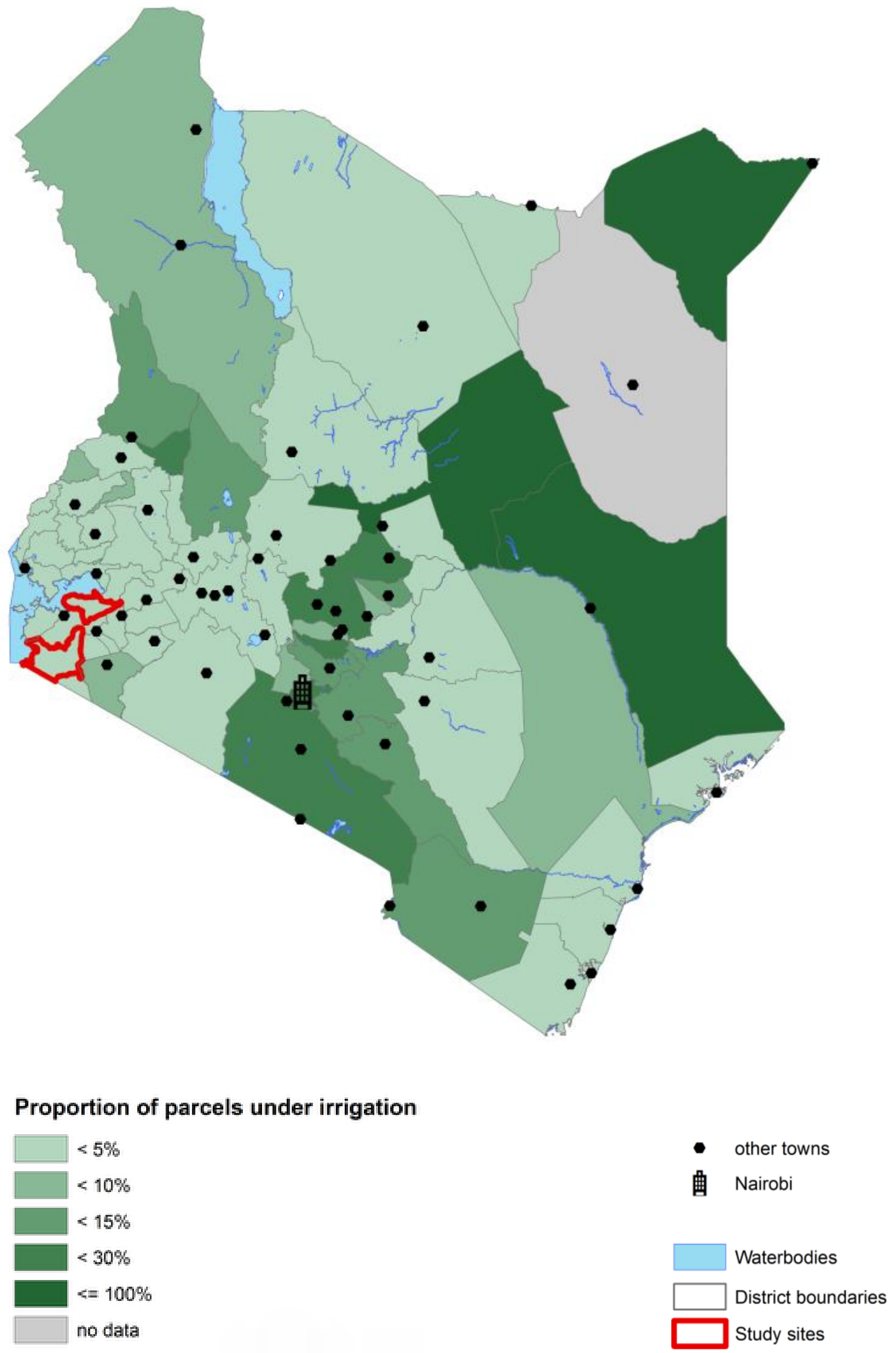
[65] "A parcel refers to a distinct piece of land under cultivation, separate from any other areas cultivated by the household." (KNBS, 2006a, p. 159)

Map 3-2: Percentage of land under cultivation



Data sources: FAO Africover dataset, Kenya National Bureau of Statistics (2003)
Cartography: Heike Baumüller

Map 3-3: Percentage of parcels under irrigation



Data sources: KIHBS 2005/06 , Kenya National Bureau of Statistics (2003)
Cartography: Heike Baumüller

Rural infrastructure is poorly developed and markets are often located some distance away. Maintained earth roads are the most common road surface, found in about half of the communities (in 2005/06) (KNBS, 2006a). Tarmac roads are only available in 6% of rural communities while just over 70% have to travel more than a kilometre to reach a tarmac road. Just over 80% of rural communities live more than 5 km away from the nearest daily market while fewer than 10% have to travel less than 3 km (ibid). The consequent high transportation costs have been found to discourage farmers from moving into higher value cash crops, opting instead for low yielding food crops (Omamo, 1998).

In addition, Renkow et al. (2004) show that economic isolation of households, i.e. remoteness and where animals and bicycles are the main means of transport, further increased already high fixed transaction costs of selling produce in Kenya's rural areas. Such costs include the costs of searching for markets and sellers, bargaining costs in the presence of information asymmetries and costs associated with screening and monitoring transactions. Renkow et al. (2004) estimate that on average the ad valorem tax equivalent of fixed transactions costs in their sample amounted to 15%.

A study by Olwande and Mathenge (2011) also shows that market concentration tends to be high in Kenya. Among surveyed households, the top 20% of selling households accounted for 70% of maize, vegetable and fruit sales. In particular the poor[66] produced mainly for subsistence with limited market participation. In 2007, 37% of poor households sold maize compared to 54% of non-poor households. The differences were similar with regard to vegetables and fruits. Also, the poor tended to sell significantly lower quantities due to low production volumes. The authors attributed the low production and marketing volumes to the limited use of fertilisers and improved seeds, low literacy levels, small land sizes, few assets, limited access to credit and the small surplus production.

Three types of m-services to facilitate access to output markets are available in Kenya, i.e. price information services, 'virtual' markets and supply chain management systems. To obtain information on prices for their produce, Kenyan smallholder farmers often have to rely on middlemen or word-of-mouth from other farmers.[67] A number of mobile phone-based price information services have been developed in recent years which seek to address this gap by disseminating 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*).

One Kenyan company – Virtual City – also uses mobile phones as part of their supply chain management system (*Agrimanagr*), allowing clients to record and track produce from delivery to final destination. The company notes that the system has reduced delays in paying farmers, cut purchasing times and increased average product weight. In addition, the Syngenta Foundation has trialled its supply chain management system *Farmforce* in Kenya which uses mobile phones to track deliveries from smallholder farmers to buyers.

[66] The poor were defined as those living on less than 1,598 KSh per month in 2007.
[67] Jamila Abass cited in Kimo (2011)

4 The Case of *M-Farm* in Kenya

This chapter presents the case study of *M-Farm* which aims at facilitating farmers' participation in the market by improving their bargaining position and linking them to buyers. To this end, *M-Farm* provides daily crop price information via SMS, assists smallholder farmers in collectively selling their produce, and connects buyers and sellers via an internet- and mobile phone-enabled platform. The case study examines the role of *M-Farm* in facilitating farmers' participation in agricultural technology innovation processes. Specifically, the case study assesses the extent to which *M-Farm* has influenced farmers' decision to adopt technologies and their ability to generate additional income through their use.

The first section outlines how price information and marketing support could help farmers adopt agricultural technologies and reviews the empirical literature on the role of m-services in this regard. The second section sets out the methodology used in the case study. Section 4.3 describes the history and functionalities of *M-Farm*, with a focus on their operations in the two study sites. Section 4.4 highlights the research findings regarding the use of *M-Farm* in Kenya and how the service has influenced adoption decisions and income generation among surveyed farmers. A summary of key findings is provided at the end of the section. The factors that have contributed to the expansion of *M-Farm* are discussed in Section 4.5. The final section examines opportunities and challenges for scaling up *M-Farm*.

As already mentioned above, identifying causalities between the use of m-services and agricultural technology innovation poses a particular analytical challenge, given that the adoption of agricultural technologies and m-services may both be endogenously determined by other drivers. The factors influencing agricultural technology adoption have been extensively researched (for an overview, see e.g. CIMMYT 1993; Feder et al. 1985; Feder and Umali 1993; Marra et al. 2003; Sunding and Zilberman 2001). They can be broadly categorised into four groups, i.e. the farmers' characteristics (e.g. education, age, gender, wealth, attitudes to risk), farm resources (e.g. land size, labour, finance, agricultural inputs), biophysical characteristics (e.g. water availability, cropping systems, climatic conditions) and the socio-economic context (e.g. access to markets, infrastructure, the legal and political environment, ethnic or religious factors).

The factors influencing mobile phone and m-services adoption have been less thoroughly assessed. Some of the factors identified in exiting studies are similar to those found to be influential in agricultural technology adoption:

- Phone ownership tends to be more common among higher-**income** groups (measured e.g. in terms of assets or per capita expenditure) (Mascarenhas, 2010; Muto and Yamano, 2009; Samuel et al., 2005; Souter et al., 2005). While poorer users often have access to mobile technologies through phone sharing or public phones, they were found to use the phone less frequently than phone owners (Samuel et al., 2005; Souter et al., 2005) and for a more limited range of purposes (Goodman, 2005).

- A higher level of **education** has also been found to increase the likelihood of owning a mobile phone (and ICTs more generally) (Mascarenhas, 2010; Muto and Yamano, 2009; Souter et al., 2005).

- While none of the studies looked at the role of risk and risk attitudes in mobile phone and m-services adoption, several note the importance of **trust** as a prerequisite for people to use their mobile phone in business transactions (Galperin and Mariscal, 2007; Jagun et al., 2007; Mascarenhas, 2010; Molony, 2006; Overå, 2006), presumably as a way to reduce the risk of being cheated. Overå (2006) also notes that mobile phones were more likely to be used in trading if risk-reducing sanctions were available.
- **Gender** also appears to play a role in influencing ownership and use of mobile phones (or ICTs more generally) although the evidence here is limited. Some studies find that women had less access to mobile phones than men (Diga, 2008; Mascarenhas, 2010).

Several studies have also looked at the factors shaping farmers' propensity to use mobile phones or m-services for agricultural purposes. Again, these factors are similar to some of those identified in the literature on agricultural technology adoption:

- Higher **income** was also found to positively influence the usage of m-services (Kiiza and Pederson, 2012; Kirui et al., 2010). Moreover, access to micro-loans increased the likelihood of using ICT-based market information (Kiiza and Pederson, 2012).
- Similarly the level of **education** and literacy also increased the usage of m-services (Gunasekara et al., 2011; Kiiza and Pederson, 2012; Kirui et al., 2010).
- Kiiza and Pederson (2012) also show that the likelihood of using ICT-based market information services decreases with the **age** of the household head.
- The level of **commercialisation and market orientation** was identified as another factor influencing the use of m-services (Kiiza and Pederson, 2012; Kirui et al., 2010). Related factors include proximity to a market and participation in government awareness campaigns promoting various cash crops (Kiiza and Pederson, 2012). Moreover, farmers appear more likely to use their mobile phones to search for agricultural information in areas where agriculture is profitable (Kameswari et al. 2011).
- Several studies conclude that farmers who are part of a **group** are more likely to use and benefit from m-services (Ferris and Robbins, 2004; Kiiza and Pederson, 2012; Kirui et al., 2010).
- The rate and speed of adoption was found to be higher where farmers had received **training** in the use of the service and/or could revert to a 'human interface', i.e. an intermediary between the user and the service (Gunasekara et al., 2011).
- Kiiza and Pederson (2012) also highlight the role of **gender** as an influencing factor; they find that the likelihood of access to ICT-based market information among farmers declines with female-headed households.

This review of the literature suggests that confounding factors may indeed influence the adoption of agricultural technologies and m-services. However, the study does not assess whether such effects are also at play in the case of *M-Farm*.

4.1 The Role of Marketing M-services in Agricultural Technology Innovation: Empirical Evidence and Research Gaps

The agriculture sector in many developing countries is characterised by a large number of low-input, small-scale and predominantly subsistence farmers (Eggleston et al., 2002). Productivity is generally low due to limited access to modern agricultural technologies which in turn affects market participation (Barrett, 2008). Among the obstacles to commercialization, many farmers lack information about prices and demand in different markets and contacts to potential buyers. As a result, much of the produce is consumed by the households themselves while the remainder is sold to a few traders or on local markets (Barrett, 2008; Eggleston et al., 2002).

M-services can support the emergence of markets or increase market activity by reducing the cost of accessing information and negotiating transactions (Bedi, 1999). Possible services include the transmission of market information (e.g. on prices or potential buyers), connecting buyers and sellers, or managing deliveries by a large number of small-scale farmers. The following section reviews empirical evidence as to the effectiveness of such services (referred to as 'marketing m-services' here) with regard to facilitating farmers' decision to adopt agricultural technologies and their ability to generate income from their use.

4.1.1 Decision to adopt agricultural technologies

Lack of access to price and demand information can discourage agricultural technology adoption by creating uncertainties about the expected profitability of a technology (Abadi Ghadim & Pannell 1999). Market information can help farmers assess, for instance, the likely differences in economic returns when switching to a different crop or whether to take the financial risk of investing in light of expected future returns (Marra et al., 2003). In most developing countries, price information is gathered by the government (through Ministries of Agriculture or Trade) and disseminated via radio, newspaper, internet, email, mobile phones or notice boards (Ferris et al., 2008). In practice, however, 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).

Two studies conclude that m-services providing price information have helped farmers improve their planning. *TradeNet* users in Sri Lanka said that the information enabled them to make more informed decisions about the best harvest and selling times (Lokanathan and de Silva, 2010). The study compared farmers using the service with a control group based on surveys to evaluate their perceptions of changes. An assessment of the m-service *Esoko* in Ghana also finds that farmers used the price information at the sales stage, i.e. to decide when (22%) and where (38%) to sell, but also when making planting decision (11%) (CTED, 2013). None of the studies quantified actual changes in technology adoption, productivity or income.

In contrast, Fafchamps and Minten (2012) conclude that the m-service *Reuters Market Light* (*RML*), which disseminates price, weather and farming information to Indian farmers via SMS, did not induce systematic changes in agricultural practices, such as adopting new varieties or changing cultivation practices. The authors do not differentiate between different types of information delivered by the service when assessing impacts. Interestingly, where farmers did change their behaviour, those being offered *RML* subscriptions were more likely to list *RML* as an inspiration for the change even though there were no statistically significant differences in their behaviour compared to farmers who were not offered *RML* subscriptions.

To what extent marketing m-services have encouraged investments in new technologies has not been empirically assessed. Anecdotal evidence suggests that information about premium prices accessible through mobile phones and the radio has incentivised Ugandan farmers to invest in post-harvest technologies (Ferris et al., 2008).

4.1.2 Income generation

Lack of market information and linkages can lower 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). Lack of market information and linkages can also lead to high price dispersion, where prices for similar goods vary widely across different markets, which in turn leads to inefficient allocation of produce across markets (Jensen, 2007; Stigler, 1961).

A number of studies have assessed the role of marketing m-services on income gains and sales patterns:

Price information

Research findings on the impact of price information m-services on income are mixed. To assess income gains, existing studies commonly focus on changes in prices that farmers receive for their produce. Two studies conclude that famers were able to obtain higher prices for their crops when using m-services to access price information. In Bangladesh, all farmers who regularly received price updates through *PalliNet* felt that their income had improved as a result of using the service (Islam and Grönlund, 2010).[68] Similarly, users of *TradeNet* in Sri Lanka said that they had earned more for their produce (Lokanathan et al., 2011). While they did not seem to use the information for bargaining, they nevertheless felt that the traders offered them better prices because they knew that farmers were aware of prices in other markets.

Similar findings also emerged from studies of price information services delivered through other ICTs, such as internet kiosks (Goyal, 2010) or radio (Svensson and Yanagizawa, 2009). The latter study concludes that Ugandan farmers who could access price information via the radio were able to obtain 15% higher prices than those without access to a radio (Svensson and Yanagizawa, 2009). The authors attributed the price increases to improved bargaining. Another study of the service also finds, however, that

[68] 36% of farmers said that their income had increased by 10-20% and 8% of farmers by 20-25% while the remainder did not quantify the increase (Islam and Grönlund, 2010).

only 40% of farmers used the price information to bargain for better prices although 76% used the service to learn about price (Ferris et al., 2008).

An on-going study into the impact of the price information service *Esoko* on Ghanaian farmers finds that impacts on prices differed between crops. Thus, users obtained higher prices for yam (11%), but not for maize, cassava, and gari (processed cassava) (CTED, 2013). Information on the method used to assess price gains is not available. The authors suggest that the difference may be due to the fact that bargaining is more common in the case of yam marketing than other crops. This hypothesis is supported by the fact that around two thirds of farmers said that they had used the price information to bargain with traders. Another study of *Esoko* pointed to 10% price increases for maize and groundnuts, but could not rule out confounding effects from farmers participating in other *Esoko* activities (Subervie, 2011).

Three experimental studies come to different conclusions, however. A study in Colombia shows that although many farmers who received daily price information via SMS were more knowledgeable of prices in different markets, they did not receive higher sales prices than those who did not use the service (Camacho and Conover, 2011). The study compared prices recorded by farmers with average daily prices collected by the Corporación Colombiana Internacional. The authors do not offer an explanation for this finding.

Similarly, Fafchamps and Minten (2012) find that farmers with a free one-year *RML* subscription did not receive significantly higher average prices. They also conclude that the *RML* subscription did not impact transaction costs[69] nor did it induce farmers to economise on the cost of searching for price information. The authors note that most farmers sell at the nearest wholesale market, thus limiting their opportunities for arbitrage. Supply-side factors and technical problems with the service can also not be ruled out. Besides, establishing causalities between the m-service and observed changes is challenging since the study mainly looks at farmers who were offered a free one-year subscription, but did not differentiate impacts based on actual usage patterns (including type of information used).

A study of potato farmers in West Bengal, India, also concludes that farmers with access to daily price information (either via mobile phones or an information board) did not obtain higher average margins than farmers in the control group (Mitra et al., 2013). The study did not differentiate between the sources of price information and therefore offers no insights specifically on the role of mobile phones in disseminating price information. Some findings are nevertheless worth mentioning here. When breaking down the data, price information was found to have an impact on sales volumes (i.e. if the price is low, farmers sold less produce and vice versa). A similar trend was observed for prices. "Thus the treatment increases the volatility of farmer revenues while leaving average revenues unaffected" (p. 33). The authors attribute this finding to the nature of the potato supply chain in the region, in particular farmers' lack of direct access to the wholesale market and the low number of and therefore limited competition between traders. Thus, farmers are unable to profit from the price information if their outside options remain unchanged.

Market linkages

Studies on the role of m-services to support market linkages indicate that even where farmers know of different prices or buyers, other reasons often prevent them from switching

[69] Including the cost of transport, loading and off-loading, payment at checkpoints, personal transport, processing and commissions

traders. The study of *PalliNet* in Bangladesh shows that around a third of farmers with access to price information had switched markets at least once, but most preferred to stay in the same market because they were not familiar with the business mechanisms in other markets (Islam and Grönlund, 2010). Similarly, the *TradeNet* study finds that users with access to information about and interaction with different traders (through the *TradeNet* marketing platform) largely continued to sell to the same traders because they depended on them as a source of loans and information (Lokanathan et al., 2011). As elaborated in Section 2.2.4, most studies looking at the effect of mobile phones usage in general on trading patterns had also found limited impact.

Anecdotal evidence also suggests that 'virtual' market places may need additional support measures if they are to reach smallholder famers. Reviewing past experiences with *Cellbazaar*, the founder Kamal Quadir and his colleague Naeem Mohaiemen reflect that uptake had been faster in urban than rural areas (Quadir and Mohaiemen, 2009). Reaching farmers was found to take some additional effort in the form of "human translation or help" (p. 71), including training through public and private institutions.

Combining market information and linkages

To the author's knowledge, no study has to date examined the impact of linking price information and marketing m-services to assess how the two functions interact and can complement each other. Research by Ferris et al. (2008) on market information services provided to Ugandan farmers through radio and SMS have yielded some interesting findings in this regard which are relevant to this case study. The study finds that farmers managed to obtain the highest price gains if they were members of a farmer group, sold collectively and had access to collective storage (to allow for speculative trading) (Table 4-1). The authors conclude that:

> the likelihood of improving market performance increases when farmers combine the use of market information with collective marketing, as the group provides a stronger platform to negotiate for better prices as buying a bulked product is more attractive to buyers than buying in small lots from individuals. (Ferris et al., 2008, p. 10)

Table 4-1: Price gains within product types

	MIS + group	MIS + group + location	MIS + group + storage
Bananas	45%	60%	
Beans	31%	63%	158%
Coffee	32%	71%	156%
Maize	28%	49%	77%
Mean	45%	61%	130%

Note: The figures are for increases in gross margins and do not take into account the additional marketing and transactional costs that may have been incurred through alternative sales methods.
Source: Ferris et al. (2008)

4.2 Case Study Methodology

To collect potential case studies, a list of m-services was compiled through a desktop review of m-services accessible to Kenyan farmers and a series of interviews with m-service providers in Kenya in April 2012 to ascertain the providers' interest in the case study and data availability. The following criteria were applied to select the case study:

- Facilitate adoption of agricultural technologies
- Available in high potential areas (see below)
- Operational for at least one year
- Run by a private Kenyan company
- Package of services provided
- Data available on uptake and use of the m-service

A combination of qualitative and quantitative research methods was applied in the case study. Semi-structured interviews with academics, private sector representatives and non-governmental organisations working in the areas of agriculture and m-service development were carried out in Nairobi and Nyanza province to gather information on the agricultural context and m-services in Kenya. The interviews were guided by a number of broad questions which were adapted to the respective interviewee (see the Annex for a list of questions and interviewees). *M-Farm* staff and others involved in the development and implementation of *M-Farm* were also interviewed. In addition, focus group discussions were held in the study sites with women farmers, women and men farmers and agriculture students.

Regarding quantitative data, the SMS received by *M-Farm* between 23 March 2011 and 7 June 2012 were analysed to assess the distribution of price queries by crops and markets. The 3865 SMS were sorted by types of SMS (including price enquiries, selling, buying and other messages). The price enquiries were analysed with regard to the market and crop they enquired about. The error rate of price enquiries was also estimated, including the types of errors (incorrect command, market, crop or spelling). The SMS to sell or buy goods were dropped from the analysis because of the small number of related SMS received by *M-Farm* during the study period.

Moreover, a questionnaire-based survey of 115 farmers using *M-Farm* was undertaken in Rachuonyo and Migori districts (Nyanza Province) in May 2012.[70] The survey includes households who have access to price information from *M-Farm*. The questionnaires were administered by six enumerators from the region fluent in the local language. The enumerators were free to choose the language of the interview depending on the language preferences of the interviewee.

[70] The survey data and questionnaires are available in the ZEF Data Portal at https://data.zef.de/?uuid=28f5131c-0f0b-4c86-8e6e-19f905fb77f1.

Questions covered:

- General information about the household
- Information about the farm
- Access to agricultural technologies
- Access to markets
- Use and impact of *M-Farm*
    - price information in Rachuonyo and Migori
    - group selling in Migori
- Information about mobile phone access and usage

The two study sites were chosen in collaboration with the *M-Farm* team by overlaying the areas where *M-Farm* is offering price information and group selling with a map of high potential areas for agricultural development and poverty reduction (Map 4-1). The map was generated using the Geographical Information System (GIS) software ArcGIS, based on the methodology developed by Graw and Husmann (2014). It overlays three indicators: high agricultural potential, high poverty mass and high yield gaps.[71] The data sources and cut-off points for each indicator are provided in Table 4-2. Choosing two areas with different services, i.e. one where farmers only received price information (Rachuonyo) and one where they were also engaged in group selling (Migori), allowed for a comparison between the impact of the two types of services.

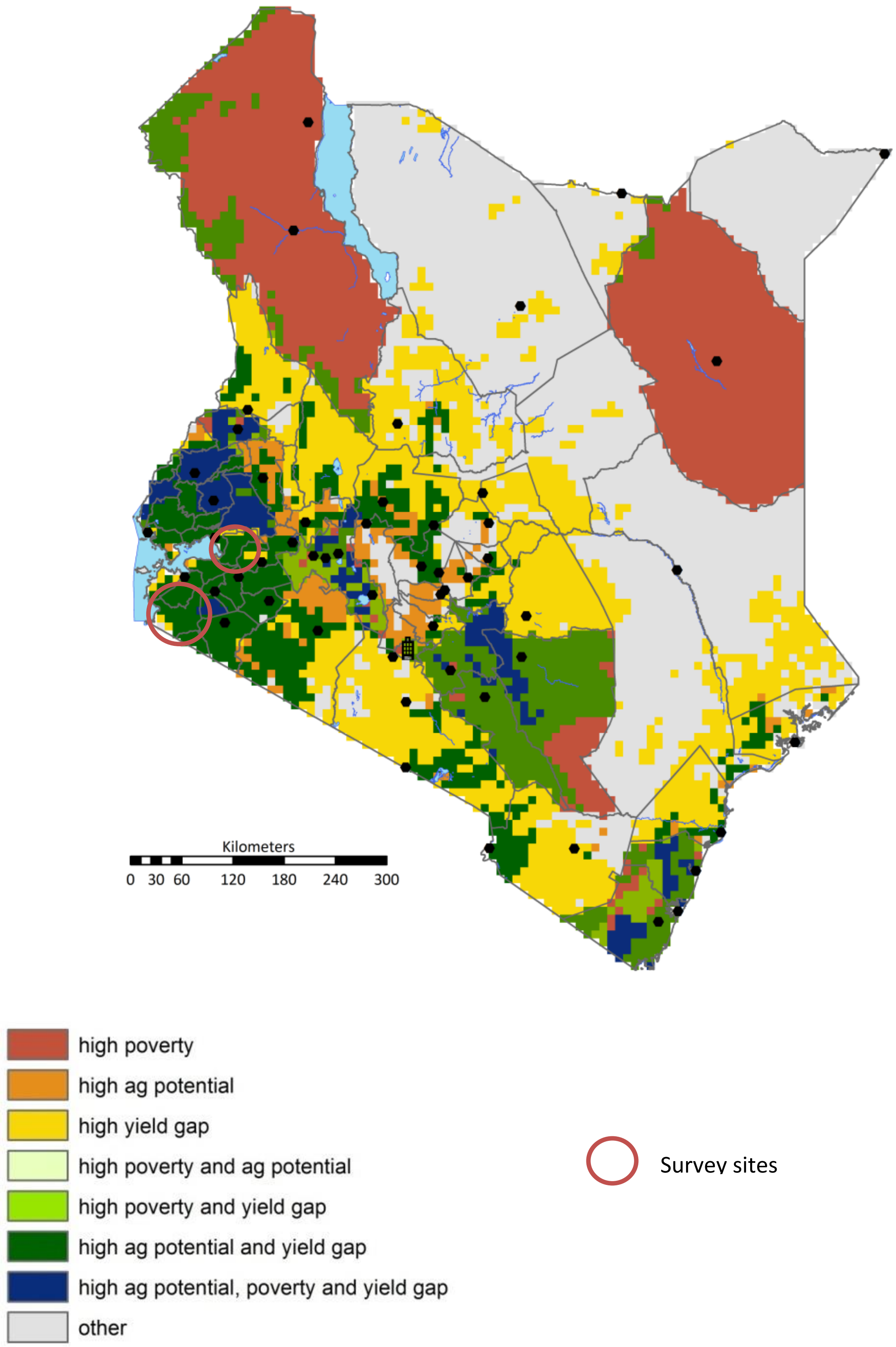
In Rachuonyo district, 70 farmers from three villages (Rongo Pala, Miriu and Kawuor) were interviewed. The famers were randomly chosen among 178 members of the *Kabondo Sweet Potato Marketing Cooperative Society*. The farmers had access to price information through *M-Farm*. 31 men and 39 women participated in the survey. 60% of respondents were also the household head, including 14 women. Where the household head was not present, the spouse was interviewed in most cases.

In Migori district, 45 *M-Farm* users from five zones[72] (Kilimanjaro, Milimani A, Milimani B, Wuok chieng and Yao) were interviewed, representing the households that are participating in the *Manywa Fruit Growers Organisation*. The farmers could access price information through *M-Farm* and sell passion fruits to the Kenyan export company East African Growers (EAG) under a contract facilitated by *M-Farm*. 25 men and 20 women were interviewed. Almost two thirds of interviewees were also the household head (62%), including three women, while most of the remaining respondents were married to the household head.

[71] One shortcoming of this approach is important to note here. The data sets use different spatial scales, ranging from ca. 10 km2 for agricultural suitability and yield data to district level in the case of the poverty data. The map therefore only offers a very general indication of high potential areas. For a more accurate picture, the poverty data would need to be broken down further to account for variations within districts. This data is not available, however.

[72] The zones were established by the Manyway Fruit Growers Organisation.

Map 4-1: High potential areas for agricultural development and poverty reduction in Kenya



District boundaries: Kenya Central Bureau of Statistics (2003)
Data sources: see Table 4-2
Cartography: Heike Baumüller

Table 4-2: Data used to identify high potential areas

Indicator	Data	Year	Type	Cut-off point	Sources
High potential for agricultural production on available land	Suitability of currently available land area for rainfed crops, using maximising crop and technology mix	2005	Global raster data layer with 5 arc-minutes resolution	High: top 3 suitability classes (medium high, high and very high)	FGGD Map 6.61; (FGGD, 2007)
High poverty mass	Number of poor people in Kenya (by district)	2005/ 06	Shape files at district level	High: >300,000 per district	District Poverty Data KIHBS (KNBS, 2006b)
High yield gaps	Yield gap for a combination of major crops	2000/ 05	Global raster data layer with 5 arc-minutes resolution	High: < 0.25 (on a scale from 0-1, with the highest value in Kenya ca. 0.44)	FAO/IIASA - GAEZ (2010); IIASA/FAO (2012)

4.3 *M-Farm*[73]

4.3.1 Conception and Development of *M-Farm*

The initial idea

M-Farm was launched in October 2010 by a small Kenyan start-up company as an m-service targeted at smallholder farmers in Kenya. The company managed to procure seed funding of KSh 1 million (ca. EUR 8600 in October 2010) after winning the IPO48 competition in Nairobi, a boot-camp which challenges entrepreneurs to develop and pitch mobile and web services in 48 hours. At the time, the all-female team of software developers was based at the innovation space iHub in Nairobi.

Three members of the original team are still running the company along with their growing staff: Jamila Abass, a software engineer and now the CEO of *M-Farm*; Susaneve Oguya, a mobile app developer and now CTO; and Linda Kwamboka with a background in Business and Information Technology and now Marketer. For the first two years, the company was able to set up their operations in the m:lab in Nairobi which provides office space and other support for Kenyan technology start-ups. The company later moved to regular offices in the same building.

Jamila Abass describes *M-Farm* as "an SMS and web-based application focused on improving weaknesses in the value chain" (Ekiru, 2011). The initial idea was developed in

[73] Unless otherwise states, information presented in this section was collected during interviews with Susaneve Oguya (*M-Farm*), Angela Crandall (iHub Research), Ken Mwenda (eMobilis), Vincent Orwa Alila (ADS), Tobias Moga (sweet potato cooperative in Rachuonyo), Samsong Ochieng (passion fruit farmers group in Migori) and *M-Farm* users. The interviews were held in April-June 2012.

response to newspaper reports on challenges that farmers face in Kenya. Similar to farmers in other developing countries, Kenyan smallholder farmers often have to rely on middlemen for information on produce prices or on word-of-mouth from other farmers. Government-provided data is only available on a weekly basis, not always reliable and often in weight units that differ from those commonly used by farmers. Farmers also have limited choices of who to sell to, lacking information on demand and contacts to potential buyers in other markets. Payments can be delayed because buyers tend to take a long time to pay farmers and coops often lack a clear system to keep track of payments.

To address these constraints, *M-Farm* provides information on market prices and improves market access by linking farmers and buyers. Thereby, *M-Farm* aims to help farmers decide what to grow and when to sell their crop, and improve their bargaining position vis-à-vis buyers through information on current prices and by achieving economies of scale through group selling. As Susaneve Oguya notes, many of Kenya's smallholder farmers are not necessarily poor, but "poor at managing their resources"[74], lacking both entrepreneurial attitudes and skills. As a longer term aim, *M-Farm* hopes to improve food security within Kenya by encouraging farmers to diversify their crops and facilitating internal food distribution through intra-Kenyan trade.

M-Farm offers three functions:

Price information for produce: *M-Farm* provides wholesale market price information on six days per week (Monday–Saturday) 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 ("price crop market"). The information is also available through the website and two apps. The information is gathered by data collectors who are equipped with internet-enabled phones to upload the data to the central database.

Selling produce: *M-Farm* connects farmers and buyers to enable farmers to sell produce directly and as a group. To sell their produce through the marketplace, farmers first have to subscribe to the service by sending a message to the short code ("Join firstname lastname location"). They can then send an SMS to the same number if they would like to sell their produce ("sell crop weight price"). Offers are posted on the website where buyers can contact the supplier directly to express their interest in purchasing the crop.

Buying inputs: *M-Farm* also offers a service to enable farmers to collectively buy farming inputs in an effort to get better prices for bulk purchases. However, the service has been put on hold (see below).

[74] Susaneve Oguya, *M-Farm*, pers. comm. 1 May 2012.

Following a one-year pilot phase in Kinangop, *M-Farm* has now expanded to other divisions and by June 2012, more than 5400 farmers were using the m-service.[75]

Dealing with realities

Since its launch in 2010, *M-Farm*'s business plan has undergone numerous iterations in response to experiences gained during implementation. Jamila Abass points out:
The most difficult thing was getting the business model right. When you're sitting in your office, you think that your business model is really set. It isn't. When you go out into the real world, launch the product and hear what the people who are supposed to use the product say, everything changes. (cited in Kimo, 2011)

While the three main functionalities of *M-Farm* have largely remained unchanged (price information, selling produce and buying input), the timing and details of the implementation were adjusted over time. *M-Farm*'s operations also evolved with regard to marketing, financing and data gathering.

Price information – Ensuring reliability, expanding dissemination channels

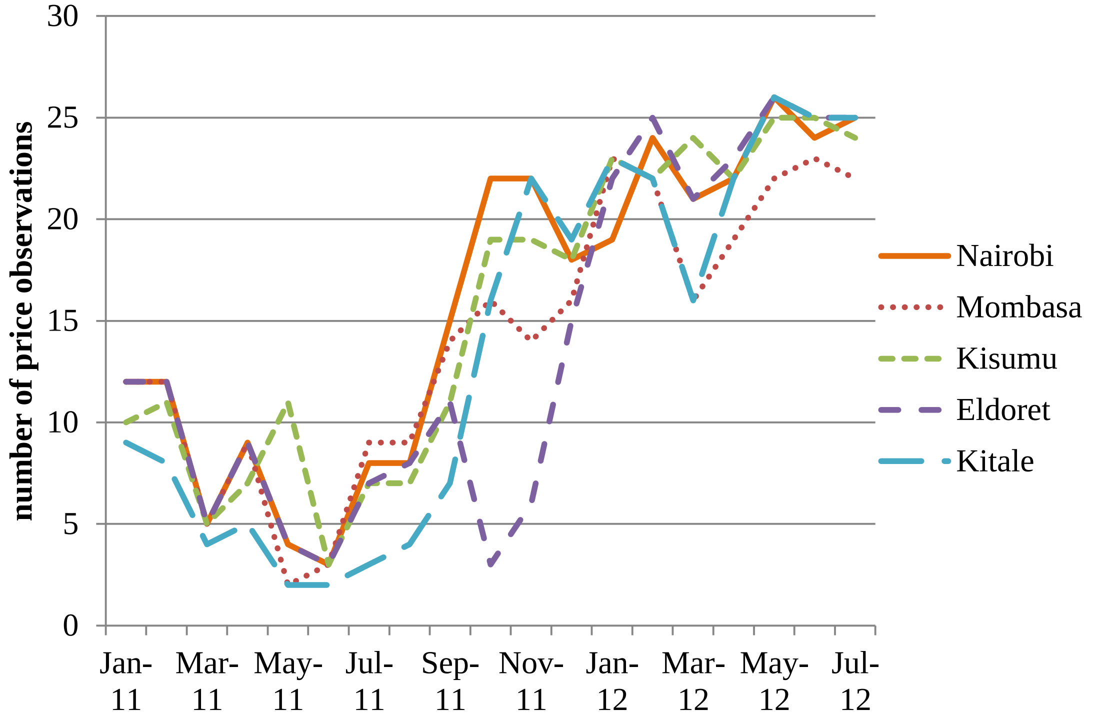
M-Farm's price information has become the company's flagship service. A number of hurdles had to be overcome in the initial phase of operations. Ensuring reliability of data collection turned out to be a particular challenge. The company started out with one data collector per market who was charged with gathering wholesale prices. However, especially in the first few months, price information could not be obtained on some days due, for instance, to the seasonality of crops or various human factors (e.g. data collectors lost their phone, one collector did not report or network coverage was unavailable). The *M-Farm* team was also concerned that the data reported by the collectors may be invented.

To ensure reliability of data, *M-Farm* developed a number of strategies. They employed a second collector for each market to cross-check the information. They also provided collectors with GPS-enabled phones to track their location and thereby make sure that they indeed entered the market. As a result, data gathering has become more consistent since September 2011 even though reporting frequencies still vary for some markets and months (as can be seen from the example of sweet potato prices in Figure 4-1).

M-Farm also faced some technical challenges at the beginning. Farmers using the Safaricom network sometimes experienced time lags or failure to deliver the price information, caused by the agent through which the SMS had to pass. *M-Farm* has since switched agent to avoid these problems.

[75] Jamila Abass, CEO, *M-Farm* @ Pivot East, 6 June 2012

Figure 4-1: Sweet potato price observations per month (Jan 2011 – July 2012)



Source: Compiled by the author using M-Farm data

In addition to price information provided through SMS, *M-Farm* has developed other ways to disseminate the information over time:

- The team found that interest in the price data was high not only among farmers because government data was only published weekly and was often not reliable. In response, they began selling data to media houses, TV and radio stations, traders, NGOs and restaurants either in raw format or as a package of analysis and data. *M-Farm* also provides analyses of price trends, using government data from 2005-2010 and *M-Farm* data subsequently.
- Prices and price trends are also available on the *M-Farm* website.
- In June 2012, *M-Farm* launched a mobile phone application for Samsung smartphones which offers price information for all crops and markets for the past five days of the week. The app is available free of charge from the Samsung app store[76].
- In May 2013, *M-Farm* also launched an app on the Google Play Store (in partnership with Samsung) which can be used on all Android phones. The app provides the same price information as well as price trends and entries from the *M-Farm* blog. The app is mainly targeted at near-city farmers who want to sell their produce through *M-Farm*.

[76] www.samsungapps.com/topApps/topAppsDetail.as?productId=G00006381375 (accessed 12 June 2012)

Selling – From SMS-enabled group selling to contract farming to an open market

M-Farm sought to deploy an SMS-based system that would enable farmers to coordinate the planting, harvesting and/or delivery of their produce, thereby enabling them to sell collectively. In practice, the main avenue for selling produce has been through contracts for specific produce with buyers which are facilitated by *M-Farm* and a local aggregator, i.e. people or organisations who are trusted in the community and can tap into existing networks, such as community-based organisations, non-governmental organisations or women leaders (see also Section 4.3.2 for a detailed description of the selling arrangement illustrated with the case of passion fruits from Migori district). Such arrangements are already in place in Kinangop (peas), Homa Bay (mainly groundnut), Migori (passion fruit), Mombasa (avocado), Eldoret (passion fruit, wheat), Kitale (potato, tomato, maize) and Bungoma (mainly onions) (as of May 2012).

At the time of the field research (April-June 2012), the originally envisaged SMS system was only used to coordinate selling and buying via the website. Usage of the online marketplace was limited primarily to urban farmers without access to an aggregator or buyer while most of the trading took place under contracts. However, since then, *M-Farm* has decided to shift attention from contract farming for export to facilitating the open (domestic) market via the online platform.[77] The team had found that farmers were facing difficulties in selling their produce on the export market because they could not afford the necessary certificates. As a result, most export-oriented farmers have not been trading since early 2013.

The mobile phone-enabled open market is aimed at helping farmers obtain better prices for their crops than what they can obtain at their local markets. Farmers located near Nairobi can post their crops directly to the website. Once a buyer has decided to purchase the produce, the two parties can decide whether they want to finalise the transaction independently or via *M-Farm*. Many buyers prefer selling through *M-Farm* against a commission to ensure the quality of the crops. To this end, the farmer takes the goods to a collection and verification point in Nairobi where *M-Farm* staff check the quality before the buyers comes to pick it up.

M-Farm is also working to facilitate access to the open market in other districts through their aggregators. The aggregator sends an SMS to the farmers to inform them about the crops that a buyer is interested to purchase. Farmers can then express their interest in selling their crops by sending an SMS to the short code, including a unique identified for each farmer. The information is posted on the website. If the sale is approved by the buyer, the farmer supplying the crop sends another SMS to confirm the transaction. The quality is checked by the aggregator. The buyer is then responsible for the transport.

Payment for the crops sold on the open market is managed through *M-Farm* which receives the money and transfers it to the farmers via *M-Pesa*.

Collective buying – Putting the cart before the horse?

M-Farm launched a service for famers to source fertilisers and solar lamps as a pilot, but quickly encountered a number of challenges:

[77] Since this change took place after the time of field research, it will not be assessed in more detail in the remainder of the dissertation. Rather, the status of the service as of June 2012 will be used as the basis for the analysis.

- **Famers' liquidity:** A major constraint was the financial liquidity of the farmers who did not have the capital to purchase the goods (due e.g. to low or seasonally fluctuating incomes or lack of financial skills so manage their saving). Also, especially in the early stages of *M-Farm*, some farmers did not trust the service enough to pay the money upfront.
- **Financial viability:** The sale of fertiliser was not economical for *M-Farm* because the discounts were not sufficiently high to obtain a viable margin for the company. This was further exacerbated by a government initiative to offer special deals on fertiliser purchases. Also, without sufficient economies of scale from a large user base, *M-Farm* struggled to get the product out logistically.

To address these challenges, *M-Farm* entered into collaboration with a cooperative. The coop received a discount of 30-50% if they sold the fertiliser to the entire group of about 800 farmers. However, this initiative also failed because of liquidity constraints of the farmers who were not able to pay the coop in cash, and because the coop did not pass on the savings to the farmers.

As a result, the service was put on hold after the initial pilot. As Jamila Abass recalls,

> we planned to start our relationship with the farmer from the time they put the seed in the ground to the time they harvested the crop. Apparently, it needs to be the other way around. You start from the time they harvest – that's the beginning of the business cycle. If you don't help them sell, they don't have the money during the planting time, and then you can't sell any other services to the farmer. (cited in Kimo, 2011)

M-Farm has now decided to wait until the farmers have sufficient liquidity to purchase the inputs. They also teamed up with Equity Bank to offer training on financial literacy.

Marketing – A key challenge

One of the main challenges has been marketing to small-scale farmers. Jamila Abass recollects:

> Like any other new thing, acceptance of our platform has not been easy amongst farmers. Most of them only use their phones for voice services and do not look at other ways of making it a business tool. The SMS platform itself is challenging and therefore we have to train farmers on the formats. We have had to conduct outreach programmes, mostly in remote areas because that is where farmers are. Conducting publicity campaigns in such remote areas is no walk in the park. (cited in Ekiru, 2011)

The *M-Farm* aggregators in the districts have played a key role in raising awareness of the service, providing training for potential users and facilitating the group selling. *M-Farm* also approached local leaders in the communities to encourage them to spread the idea.

Marketing has also faced some technical challenges. After four months of operation, the mobile service provider changed the short code, requiring a new marketing and retraining campaign of existing customers (Kimo, 2011). *M-Farm* again changed its short code in June 2012 from 3535 to 3555 to reduce the cost of SMS from 10 to 1 KSh, requiring yet another marketing campaign (although the old short code still worked, albeit at a higher cost). In July 2013, the short code changed again to 20255 when Kenyan MNOs moved from 4-digit to 5-digit short codes. This short code is only available for Safaricom users. The 4-digit codes are no longer operational. The cost of the SMS remains 1 KSh. *M-Farm* is likely to have lost some customers during the last change, but maintained the most active users who contacted Safaricom or *M-Farm* to find out why the 4-digit short code no longer worked.

As will be discussed below, high error rates in the SMS price enquiries indicate that significant gaps in marketing remain. The analysis of price enquiries shows that many farmers are not aware which markets or crops they can enquire prices for or how to send the message. With the 3535 code, users who made a mistake either did not receive a response or a message saying 'unsupported keyword'. With the subsequent short code 3555, an automatic message was sent in response to errors with instructions on how to word the message. While instructions for using the service, including the markets, are available on the *M-Farm* website, only a small fraction Kenyans (5% in 2005/2006) have access to the internet (KNBS and CCK, 2011). Information on crops is not available on the website.

Financing – Diversifying funding sources

M-Farm's revenue sources have evolved over time. Social investors have been and continue to be an important source of finance, such as the seed funding from the IPO48 competition (through the Danish investor Kresten Buch) and techfortrade[78], a UK-based organisation that invests in social businesses. Access to potential investors is facilitated through participation in competitions (e.g. IPO48 and Pivot) and *M-Farm*'s location in the m:lab which offers them a space to interact with potential funders. *M-Farm* also became an "Unreasonable Fellow" of the Unreasonable Institute in 2012 after raising US$ 10,000 which offered them training and the opportunity to pitch their idea to potential investors.[79]

The commission paid by produce buyers for each transaction that is facilitated by *M-Farm* under contracts or in the open market constitutes the main source of revenue for *M-Farm*.

M-Farm also generates income from the price information, although the importance of this revenue stream has decreased. While *M-Farm* initially received income through the price of the SMS (KSh 10), they later found that the price was too expensive for farmers. As a result, the cost of an SMS came down to normal network rates of KSh 1 per SMS in June 2012. *M-Farm* receives KSh 0.22 per SMS while the rest is retained by Safaricom. The apps are free of charge. The SMS-based price information service is now mainly used as a marketing tool to engage farmers rather than a main source of revenue.

Other revenue sources include:

- Selling the price information to media houses. In addition, the team started a pilot in early 2013 to sell analysed price data to farmers through the *M-Farm* weekly newsletter.

[78] techfortrade.org (accessed 15 June 2013)
[79] unreasonableinstitute.org (accessed 15 June 2013)

- Cooperation with Samsung which has supported the launch of the mobile apps and is advertising in each price information SMS ('powered by Samsung') at a cost of KSh 5 per SMS.
- A subscription fee of KSh 1000 for six months paid by farmers who would like to sell their crops through *M-Farm*
- Subsidised office space at the m:lab for the first two years of operation.

Data gathering

In addition to price information, *M-Farm* was planning to gather various agricultural statistics in general and specifically for *M-Farm* users. Information on farmers that use the service but are not part of a selling arrangement is not available (other than their mobile phone number). The information on farmers (name, location and phone number) that participate in group selling is held by the aggregators rather than being centralised by *M-Farm*. Once the open market has become fully operational, *M-Farm* plans to analyse and sell the data from the transactions collected through the SMS (e.g. crops sold, prices etc.).

4.3.2 *M-Farm* in Rachuonyo and Migori

The case study focuses on *M-Farm* users in Rachuonyo and Migori districts, both located in Nyanza province (see Map 4-2).[80] The two study sites were chosen because farmers have access to two different bundles of services, thus allowing for a comparison between the two set-ups in a natural experiment setting. In Rachuonyo farmers only receive price information through *M-Farm*. In Migori they can access price information and also collectively sell their passion fruits through *M-Farm*. In both districts, the price information is also available through the radio through the weekly program *Pur mariek* broadcast by the regional radio station Nam Lolwe. This section describes the services offered by *M-Farm* in more detail as they were being implemented at the time of the field research in May-June 2012.

At 43% and 41% respectively, poverty rates in the two districts are just below the national average (see Table 4-3 for statistics on poverty rates and other agricultural and human development indicators). In both districts and especially in Rachuonyo, the majority of households are engaged in farming. As in the rest of the country, maize is the most common crop, grown by over 90% of households in both districts. Beans are also widespread, although only about half as many households grow the crop in the two districts compared to the national average. Other important crops in Rachuonyo are sorghum (62%) and sweet potatoes (25%) while in Migori sorghum (28%), cassava (19%) and sweet potatoes (11%) are also widespread.

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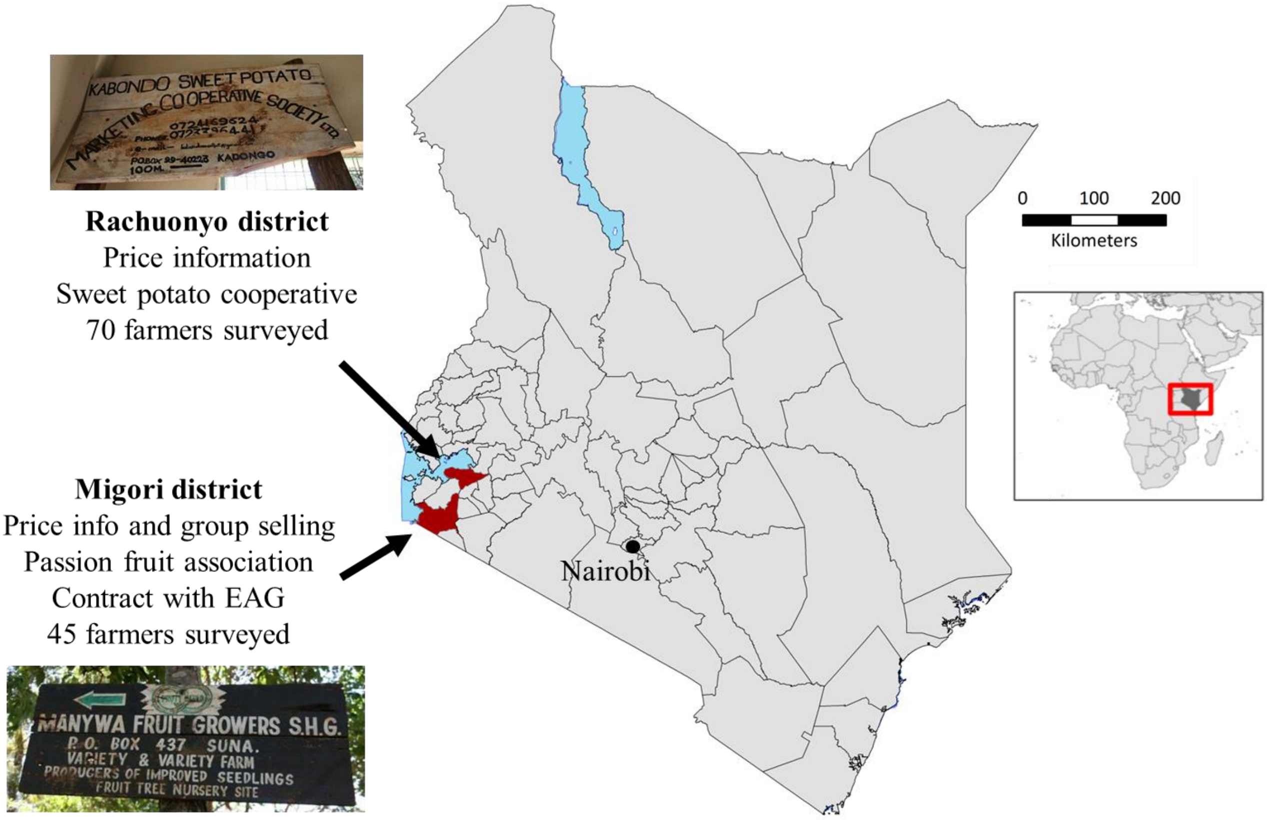
[80] In 2010, the new Constitution of Kenya changed the sub-national administrative boundaries by establishing 47 counties which will be based on (and replace) the 2009 districts. The new counties became operational after the general election in 2013. The district names and maps in this paper use the old district boundaries (from 2003) because all the secondary data was gathered before 2010 and still refers to the old districts. The GIS shapefiles showing the new county boundaries were not yet available at the time of writing.

Map 4-2: Survey sites in Kenya



District boundaries: Kenya Central Bureau of Statistics (2003)
Cartography: Heike Baumüller

In terms of agricultural technologies, Migori farmers have better access to technologies than those in Rachuonyo (using fertiliser and irrigation as proxies). Fertiliser use is fairly widespread in both districts, but Rachuonyo performs worse than the national average, with around half of the parcels using fertiliser compared to 60% in Kenya. Irrigation rates are low in both districts. In Migori, only half as many parcels are irrigated compared to the already very low Kenyan average of 6% while in Rachuonyo hardly any farmers have access to irrigation. Farmers are also located further from markets in Rachuonyo where 81% of communities have to travel more than 5 km to reach a market (similar to the national average) compared to 56% in Migori. Access to credit is higher in Migori (almost three times the national average) but also in Rachuonyo. However, only a very small share of credit received is used for agricultural inputs or machinery.

Table 4-3: Selected statistics for Migori, Rachuonyo and Kenya

	Migori	Rachuonyo	Rural Kenya	Kenya	Year	Source
Population	253,409	322,303	26,122,722	38,610,097	2009	Census 2009
Poverty headcount ratio at national poverty line	43%	41%	49%	46%	2005/06 (district) 2005 (national)	KNBS (2006) (district) World Bank[81] (national)
Literacy rate	88%	87%	76%	79%	2005/06	KNBS (2006)
Primary school completed	84%	84%	86%	86%	2005/06	KNBS (2006)
Secondary school completed	19%	17%	20%	25%	2005/06	KNBS (2006)
Stunting	33%	47%	35%	37%	2005/06	KNBS (2006)
>5 km to the nearest health facility	44%	50%	52%	48%	2005/06	KNBS (2006)
Households engaged in farming	73%	93%	84%	69%	2005/06	KNBS (2006)
Parcels using fertiliser	65%	50%	69%	69%	2005/06	KNBS (2006)
Parcels under irrigation	3.2%	0.4%	6%	6%	2005/06	KNBS (2006)
>5 km to nearest market	56%	81%	81%	80%	2005/06	KNBS (2006)
Households that sought credit	60%	37%	31%	21%	2005/06	KNBS (2006)
Credit used for ag inputs / machinery	3%	2.3%	5.8%	6.8%	2005/06	KNBS (2006)

M-Farm collaborates with the Anglican Church of Kenya Development Services (ADS) in both districts. ADS has been working with local farmers since 2007 to improve their business and marketing capacities by setting up producer groups and conducting agribusiness training. The collaboration with *M-Farm* is part of this broader enterprise development strategy.

In **Rachuonyo**, ADS is working with the *Kabondo Sweet Potato Marketing Cooperative Society*. The coop was founded in 2005 and formally registered in 2006. ADS is establishing collection centres to provide the 700+ members of the coop with central places where they can sell their sweet potatoes. Each collection centre reaches 500-1000

[81] World Bank, data.worldbank.org/country/Kenya, 2 September 2011

farmers who are organised through a collection centre representative. Farmers only harvest once they receive information about expected demand from the representative, thereby avoiding over-harvesting. The cooperative deals with the buyers and negotiates a price for all members (which was previously agreed with its members).[82] Other crops are sold at the market or to traders.

In **Migori**, ADS has partnered with the *Manywa Fruit Growers Organisation* which was established by four farmers in 1999 in an effort to reduce child malnutrition by diversifying into fruits. The group had grown to 48 members by the time of the field research and was planning to convert to a cooperative society. Passion fruit production was still in the pilot phase with around 100 farmers.[83] While the target per farmer was initially ½ acre, the plan was scaled back to ¼ acres given high upfront investment needed to start cultivating passion fruits. Farmers received 50% of the initial investment from ADS which they repay by supporting more farmers to join the group.

The passion fruits are sold to EAG under a contract facilitated by ADS and *M-Farm* (see Figure 4-2 for an overview of the collaboration between *M-Farm*, EAG and ADS). EAG exports the fruits (mainly to Israel). Contracts are signed between EAG and the passion fruit farmers[84] and between EAG and *M-Farm*. The price per kg is fixed at 80 KSh if the farmers deliver the fruits to EAG in Nairobi and 68 KSh if EAG picks up the fruits in Migori. Almost all of the surveyed farmers in Migori (96%) had entered into a contract. In most cases (44%), the contract had been signed in March 2012, i.e. two months prior to the survey. Others had signed in January (12%), February (9%) or April (25%).[85]

By June 2012, EAG had become the main buyer of passion fruits for the majority of farmers. Most of the surveyed farmers (58%) sold the larger share of their passion fruit harvest to EAG (on average 80% of what they sold overall[86], with two thirds of them selling their entire harvest to EAG). The remaining farmers still sold most of their passion fruits to other buyers (on average 68% of sales). EAG only purchases passion fruits with grade A and B quality while fruits with lower grades are sold locally.

Since production was still low (around 200 kg as of May 2012), farmers had been arranging the transport themselves (at a cost of KSh 20 per kg). EAG had agreed to collect the produce once farmers were able to deliver 4 tons. In the longer term, EAG has the capacity to take 16 tons from the farmers.

EAG transfers the payment for the passion fruits to *M-Farm* who then pays the money into the farmers' bank accounts. *M-Farm* receives a commission from EAG based on how much is sold. The farmers can approach *M-Farm* if there are any issues with their contract with EAG. The farmers were trained by ADS and EAG on how to prepare the land, manage the plants and how to sort the fruits by grades (only grade A and B are sold to EAG

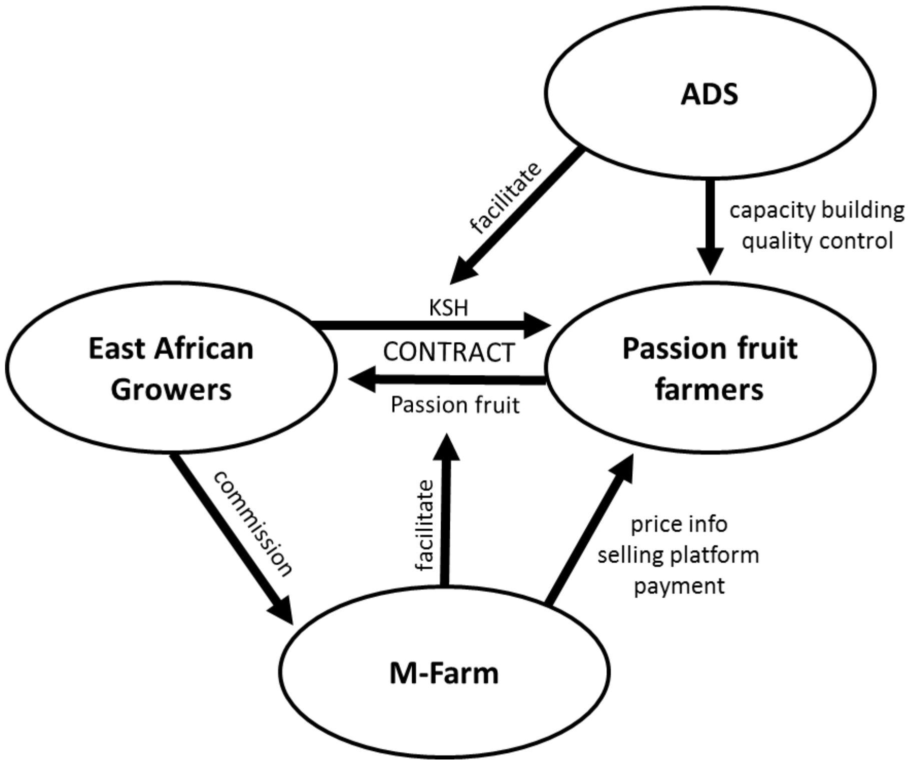
[82] ADS has also established an IT centre in Rachuonyo where farmers can access price and other farming information through shared computers (although the centre only became operational after completion of the field research).
[83] Since then, 200 additional farmers have been added to the scheme.
[84] However, farmers may not necessarily know who they had signed a contract with. While all farmers had signed a contract with EAG directly, only 63% said that they had signed the contract with EAG while the rest thought that the contract had been signed with ADS (30%) or *M-Farm* (7%).
[85] Four respondents did not specify the exact date.
[86] Only the shares were calculated rather than the absolute amounts that were sold to EAG or other buyers because respondents indicated the amounts in different units (e.g. fruits or kg) without specifying the units. The figures were therefore not directly comparable.

while the rest is sold on the local market) and package them for export. ADS continued to provide technical support through an agronomist.

At the time of the field research, the passion fruit farmers were struggling to produce high volumes. In addition to the high investment needs, lack of access to seedlings posed a significant constraint. While farmers were able to obtain their seedlings from Green Valley Orchards in Eldoret, the cost of seedlings was high. ADS was planning to establish a local nursery. The farmers are also interested in approaching EAG to obtain inputs, such as seedlings and poles. Also, farmers were not able to produce passion fruits all year round because of lack of irrigation.

The SMS-based service to coordinate the selling of crops had not been introduced at the time of the field research. It was felt that the structures needed to be in place first before the system could be used. Instead, coordination was done through phone calls where *M-Farm* contacts the group leader who in turn calls the subgroup leaders who then call the farmers. Thereby, group leaders are able to follow up with the farmers to ensure that they deliver the right fruits.

Figure 4-2: Collaboration between passion fruit farmers, EAG, ADS and *M-Farm*



Note: KSh = Kenyan Shilling

4.4 Findings

This section summarises the main findings of the qualitative and quantitative research. The first section identifies the markets and crops of interest to Kenyan farmers, based on an assessment of the SMS received by *M-Farm* between 23 March 2011 and 7 June 2012. The second section presents the results of the survey and interviews conducted in the study sites.

Specifically, the section looks at the impact of *M-Farm* on farmers' decision to adopt agricultural technologies and their ability to generate additional income, the relative role of mobile phones in delivering price information vis-à-vis other dissemination channels, and the characteristics of *M-Farm* users compared to "average" farmers in the two districts.

4.4.1 Use of *M-Farm* across Kenya

M-Farm users are primarily interested in the price information service offered by *M-Farm*. Price enquiries accounted for 77% of all SMS received by *M-Farm* during the study period.[87] Nairobi was by far the main market of interest, accounting for 44% of all price enquiries (Table 4-4 and Map 4-3). Among the remaining markets, Kisumu was mentioned in 10% of enquiries, Eldoret in 9%, Mombasa in 7% and Kitale in 3.4%. However, a significant number of SMS (21%) enquired about markets for which no price information is provided, in particular Nakuru (7%, ahead of Kitale). Overall, *M-Farm* users requested price information from 66 markets for which no information is available. 7% of SMS did not mention any market.

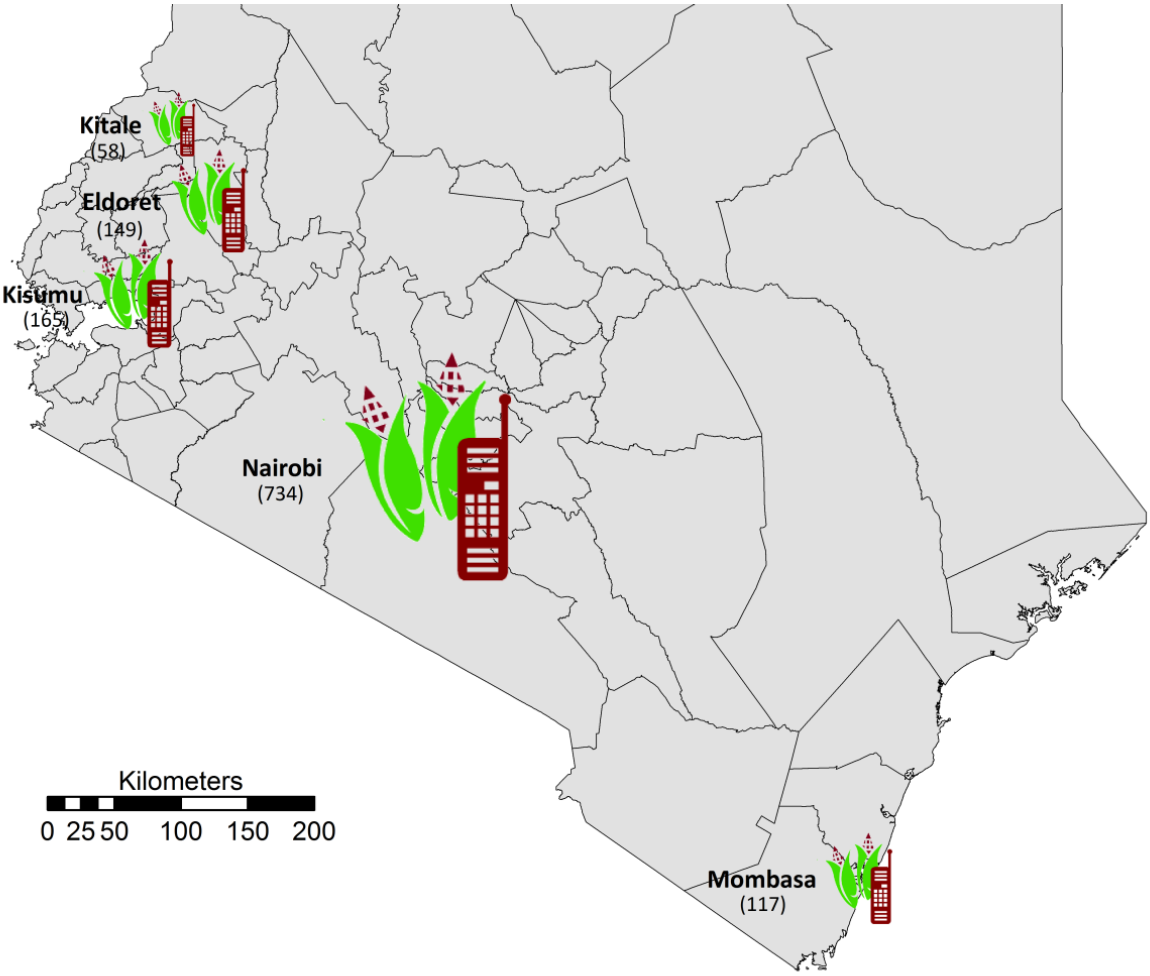
Table 4-4: Main markets and crops mentioned in price enquiries

	Total per crop	Nairobi	Kisumu	Eldoret	Mombasa	Nakuru	Kitale	Embu	Nyeri
Total per market		734	165	149	117	112	58	26	20
Tomato	376	172	28	31	25	30	14	13	7
Maize	195	69	32	28	6	16	10	1	2
Irish potato	187	73	5	38	12	17	5		2
Cabbage	116	40	13	8	15	7	4	6	4
Onion	74	31	8	3	6	10	1	3	1
Kale	67	24	13	4	3	3	3	2	
Passion fruit	59	25	8	6	10		1		2
Bean	57	25	2	8	2	4	7		
Green gram	54	11	3	4	7	4	7		1
Sweet potato	45	27	11		2	2	2		
Capsicum	31	23	2		2	2			
Egg	30	8	4	4		5		1	
Watermelon	24	14	3		3				
Banana	21	9	3	3	1				1

Note: The table indicates the number of SMS for those markets and crops that were mentioned in 20 SMS or more. 113 SMS did not specify any market while 36 SMS did not specify any crop.
Source: Compiled by the author using data on SMS received by M-Farm between March 2011 and June 2012

[87] The remainder included SMS to subscribe to the service (11%), unsubscribe (7%), purchase a solar lamp (3%), and buy or sell goods (3%).

Map 4-3: Frequency of price enquiries by markets in Kenya

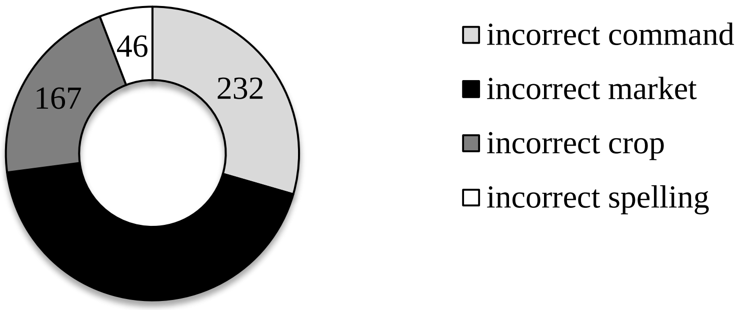


Note: Numbers in brackets refer to the numbers of SMS received per market. The map only includes those markets for which price information is available.
District Boundaries: Kenya Central Bureau of Statistics (2003)
Source: Compiled by the author using data on SMS received by *M-Farm* between March 2011 and June 2012.
Cartography: Heike Baumüller

The range of crops that *M-Farm* users are interested in is diverse, but nevertheless concentrated on a few main commercial crops. Overall, *M-Farm* users enquired about the price of 93 crops, 41 of which were included in the list of crops that they could receive price information for. The largest share of users was interested in the price of tomatoes (22%) as well as maize (12%), Irish potato (11%) and cabbage (7%) (Table 4-4). Poultry was the most frequently sought price among the products not on the *M-Farm* list although the share was low at 0.9%. Around 2% of users did not specify a crop in their SMS (and in most cases no market either).

The error rate is high at 41% of all price enquiries. The most frequent errors are enquiries related to markets for which no price information is available (43% of mistakes). Mistakes in the command (e.g. wrong word order, additional words, words missing, or several markets or crops in one SMS) as well as enquiries related to crops not included on the *M-Farm* crop list are also common (30% and 21% respectively). Only about 6% of errors are due to spelling mistakes. The majority of users made only one mistake (86%) and most of the rest (13%) no more than two in one SMS.

Figure 4-3: Mistakes in the price enquiries sent to *M-Farm*



Source: Compiled by the author using data on SMS received by *M-Farm* between March 2011 and June 2012

4.4.2 Impact of *M-Farm* in the Study Sites

Survey respondents and interviewees were generally very enthusiastic about *M-Farm*. The majority of respondents said that they had changed what they produce (79%) and the way they sell their crops (90%) because of *M-Farm*. These responses will be analysed (and qualified) in the following sections.

Two caveats need to be born in mind when interpreting the data:

M-Farm was introduced as part of a wider ADS project to facilitate the commercialisation of farmers. Given that ADS is the main contact point for *M-Farm*, farmers do not necessarily distinguish between the two organisations. Thus, impacts attributed to *M-Farm* may in fact be a result of the wider ADS project. For instance, ADS was frequently cited as the source of information about the *M-Farm* service, but the company itself only once. Similarly, training that was sometimes perceived to be provided by *M-Farm* was in fact offered by ADS as part of the wider project. Also, four farmers in Rachuonyo stated that they had used the *M-Farm* price information service for 20 months or more even though the service was only launched in October 2010 (i.e. 18 months before the survey).

Moreover, in Migori, it may be difficult to delink the impact of price information and group selling through *M-Farm*. While respondents were asked about impacts of the two services separately, it is clear from the answers that they do not necessarily distinguish between the two. This may be particularly true for farmers whose main motivation for joining *M-Farm* was to sell their passion fruit. One indication that this may be the case is that 12 of the 43 Migori farmers selling through *M-Farm* stated the same amounts when asked in two separate questions by how much the price information service and selling through *M-Farm* respectively had increased their income.

Decision to adopt agricultural technologies

The theoretical literature reviewed above suggests that improved access to timely price information can help farmers make better informed production decisions. This hypothesis is supported by the qualitative evidence collected during interviews and focus group discussions. Specially, farmers stated that the information helped them decide what crops to grow depending on the price they are likely to receive[88], whether to invest in new crops because of expected prices[89], when to harvest to achieve the best price, in which packaging sizes to sell to get the highest return per kg, and to plan their finances in the longer term because they are able to project profits. Farmers also noted that the information had helped reduce spoilage.

Results from the survey show that farmers use the price information service for decision-making during various stages of production. Most price information requests (58% of enquiries) are sent to *M-Farm* when the product is ready for sale while 28% of crop enquiries are sent prior to harvesting. This finding is confirms previous research showing that farmers use price information to decide when to harvest and sell (Lokanathan and de Silva, 2010). Moreover, similar to findings by CTED (2013), the survey also shows that farmers use price information even earlier in the production cycle, though to a lesser extent, with 13% of price enquiries sent during planting. The timing of price enquiries differs between the districts (Table 4-5). Farmers in Rachuonyo enquire more frequently in the earlier stages, in particular when then crop is ready for harvest. In Migori, prices are mostly enquired about when the produce is ready for sale. This pattern is also apparent when looking at specific crops. In the case of maize, only 15% of Migori farmers enquire about prices prior to the sales stage while in the case of beans Migori farmers only send enquiries when the crop is ready for sale. Thus, farmers in Rachuonyo seem to be using the price information more extensively for planning purposes in the earlier stages of production.

Table 4-5: Timing of price enquiries sent to *M-Farm* by district

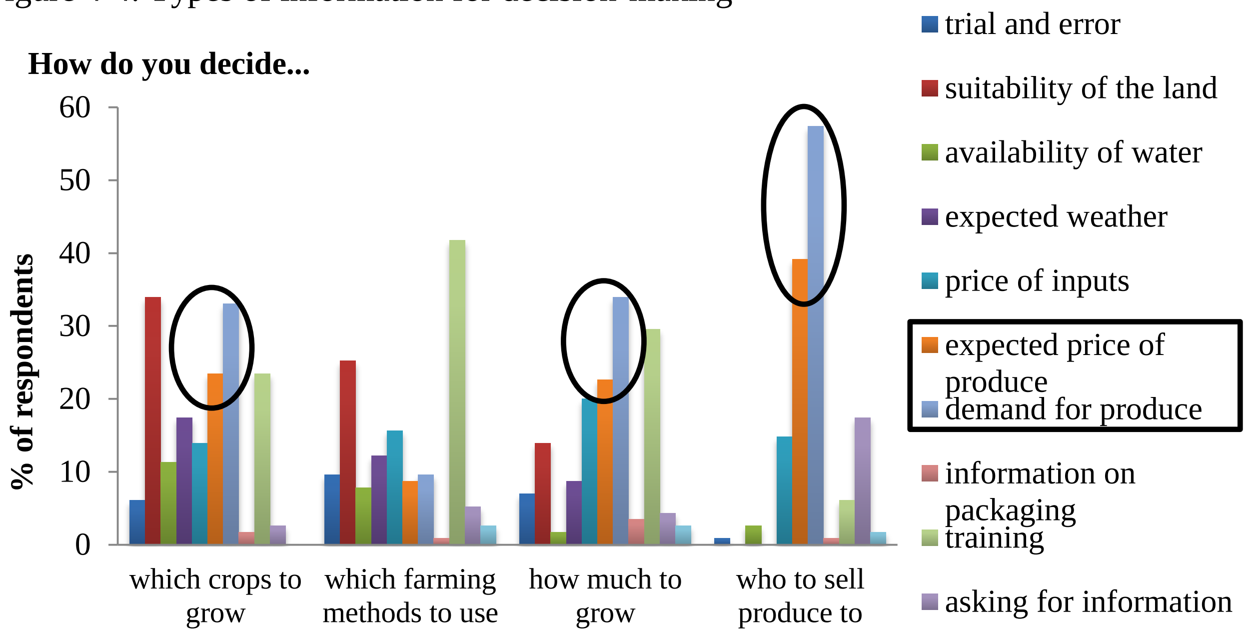
	planting	ready for harvest	ready for sale	other
All enquiries				
Rachuonyo	14	33	51	2
Migori	11	16	73	0
Maize				
Rachuonyo	17	35	47	1
Migori	5	10	85	0
Beans				
Rachuonyo	25	42	33	0
Migori	0	0	100	0

Note: The table shows the % of price enquiries per district (in total and by crops).
Number of observations: 115
Source: Compiled from survey data collected by the author

[88] E.g. one farmer in Rachuonyo said that the information about market prices for beans had encouraged him to start growing beans on his farm.
[89] E.g. the price information encouraged farmers in Migori to start growing passion fruit even though the fruit requires a high investment of around KSh 130,000 per acre per year compared to an expected return of KSh 250,000 per acre per year (Vincent Orwa Aila, pers. comm. 24 May 2012).

The survey also complements existing literature by offering general insights into the relative importance of price information vis-à-vis other types of information that farmers use for decision-making at different stages of production. Market information (including price and demand information) is cited most frequently when farmers decide who to sell the produce to, but also ranks among the main types of information at earlier stages of production, including when deciding how much to grow and which crop (Figure 4-4). Other important decision factors in the pre-selling stages of production include the suitability of the soil and training. At all stages, demand information is more widely used for decision-making than price information.

Figure 4-4: Types of information for decision-making

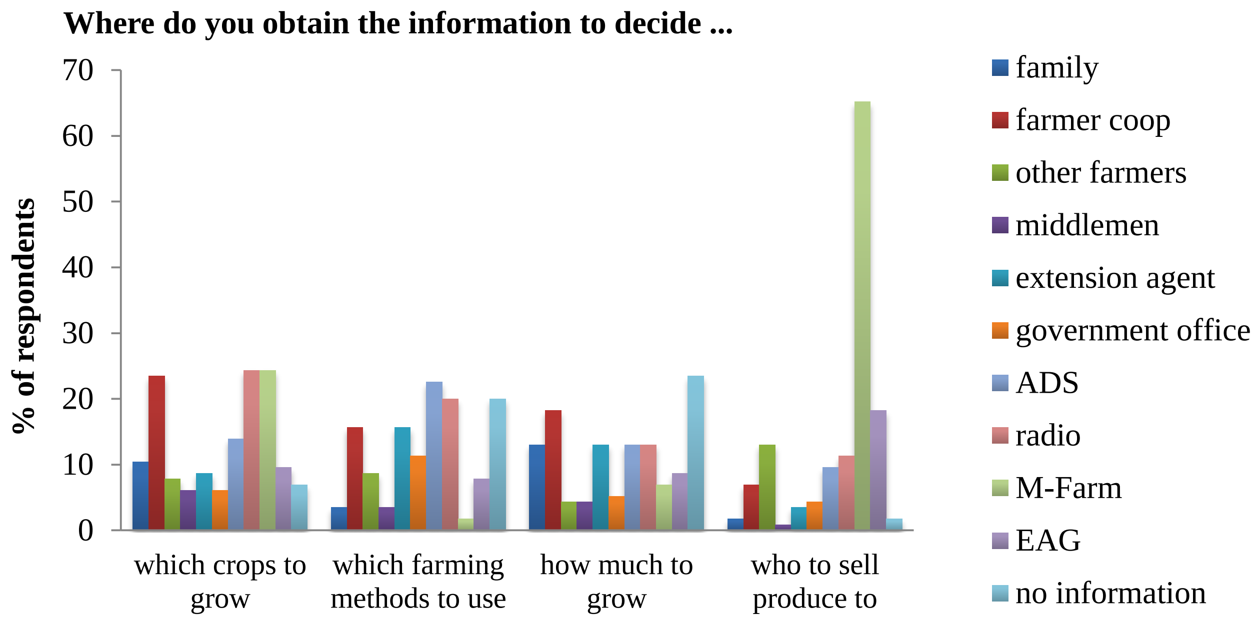


Number of observations:115
Source: Compiled from survey data collected by the author

M-Farm is cited as by far the main source of information when deciding who to sell to, but also among the most important sources when deciding which crops to grow (along with radio and closely followed by the farmers' group) (Figure 4-5). In general, farmers obtain information from a variety of sources. Newspaper, TV and agrovets were only rarely cited as information sources in the four areas of decision-making. However, many also state that they do not have any information, in particular when deciding which methods to use and how much to grow.

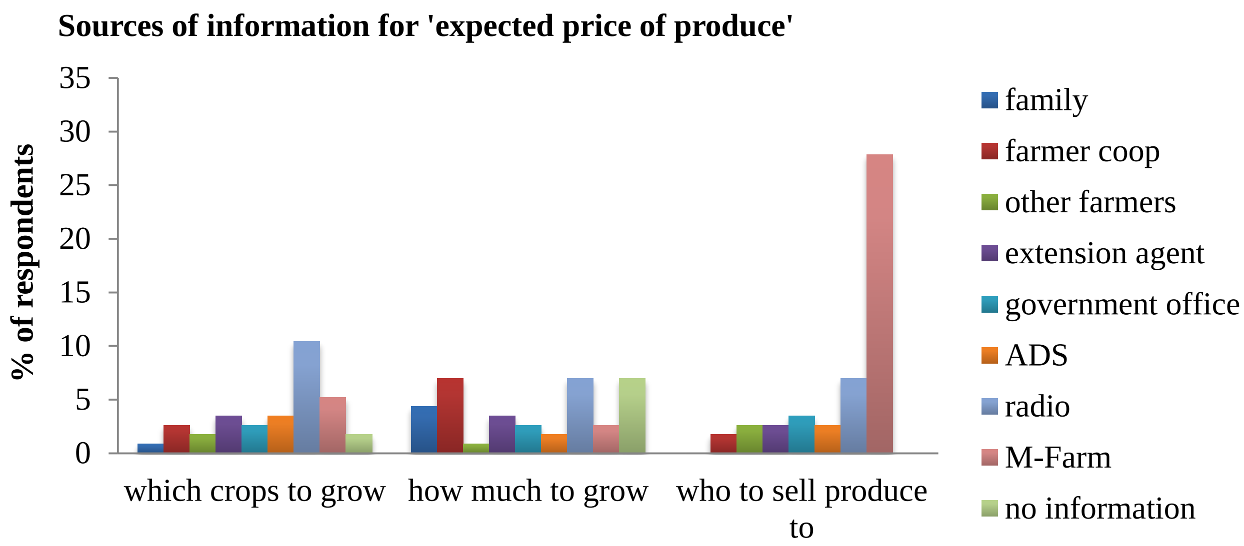
Linking types and sources of information for different stages of production shows that price information from *M-Farm* may be primarily used at the sales stage while demand information from *M-Farm* is more helpful when deciding what to grow (Figure 4-6). Instead, the radio is cited as the main source of price information at the early stages of production, i.e. when it comes to deciding what to grow. The radio is also a more widely used source of price and demand information when deciding how much to grow (see below for a more detailed comparison of radio and *M-Farm*).

Figure 4-5: Sources of information for decision-making



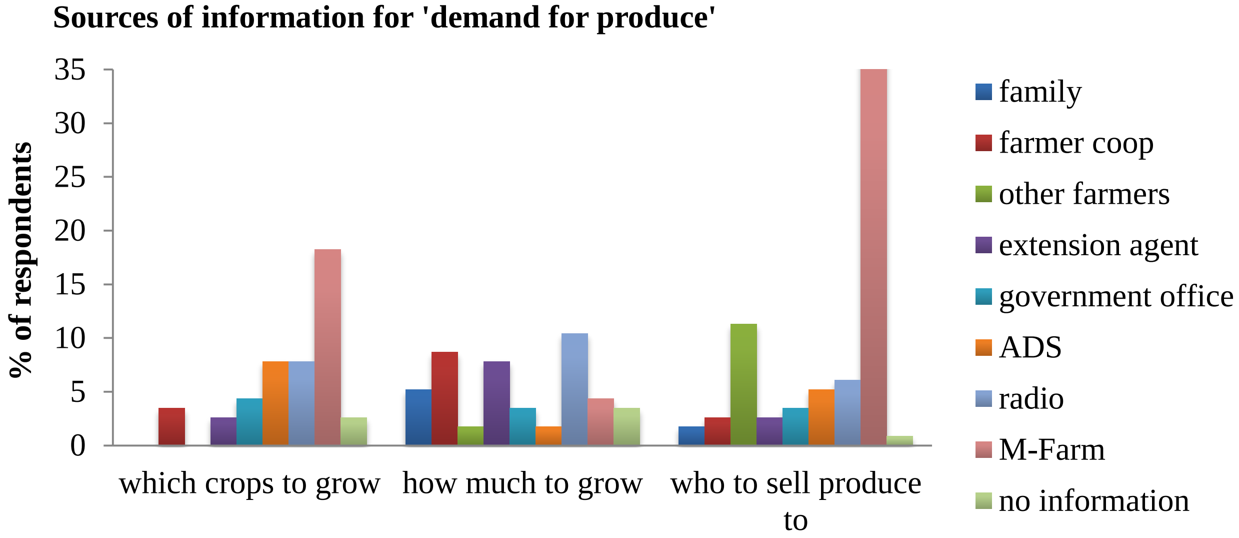
Number of observations:115
Source: Compiled from survey data collected by the author

Figure 4-6: Sources of price information for decision-making



Number of observations:115
Source: Compiled from survey data collected by the author

Figure 4-7: Sources of demand information for decision-making



Number of observations:115
Source: Compiled from survey data collected by the author

The perceived usefulness of the service is also illustrated by farmers' willingness to pay for the price information they receive. While the majority of respondents (around 59% in both districts) thought that 10 KSh per SMS was too expensive, most of them were prepared to pay more than the standard rate of 1 KSh per SMS. Thus, 88% of farmers were willing to pay between 2 to 6 KSh per SMS (3.08 KSh on average) while only 12% suggested a price of 1 KSh per SMS. Respondents from Rachuonyo were generally willing to pay a higher price for the information, with 3.3 KSh on average compared to 2.7 KSh in Migori.

The survey results outlined so far have shown that farmers are using marketing information when making farming decisions, but not whether the information has indeed translated into the adoption of new technologies. The theoretical literature cited above predicts that price information will provide an incentive for farmers to change their crop mix and/or make longer-term investments, for instance in agricultural technologies such as improved seeds, fertiliser, pesticides, irrigation or farming machines. The survey results suggest that using *M-Farm* has encouraged farmers to expand certain crops (in addition to existing rather than at the expense of other crops[90]), but was less influential in encouraging them to introduce new crops. However, the survey data also indicates that farmers may be overly enthusiastic when attributing changes in cropping patterns to *M-Farm*.

Specifically, farmers were asked whether the crop distribution on their land had changed since they began using *M-Farm* and if it had, whether the change was due to *M-Farm*. Most farmers said that they had increased production of one or more crops (Table 4-6). Of the farmers who said that they had increased production, the large majority of farmers in both districts attributed changes to *M-Farm*.

[90] It is unclear whether this was achieved by cultivating previously unused land, intercropping, crop rotation or expanding the holding size.

Table 4-6: Production changes

	increase*	increase due to *M-Farm***	decrease*	decrease due to *M-Farm***
Rachuonyo	93	95	3	100
Migori	67	93	0	0
Total	83	95	2	100

* as a share of all farmers
** share of farmers who had increased or decreased production
Number of observations: 115
Source: Compiled from survey data collected by the author

However, a closer look at the data suggests that the numbers may be unrealistically high. Overall, 87% of surveyed farmers said that they had increased maize production because of M-Farm while 56% mentioned beans (Table 4-7). Of those famers only 74% actually enquired about the price of maize and 69% about the price of beans. The difference is particularly large in Migori where 68% of farmers said that M-Farm had induced them to increase maize production but only 40% send price enquiries for maize (36% and none in the case of beans). It may be that farmers also used price information they obtained from other M-Farm users or that the changes were in fact stimulated by the broader ADS project on agribusiness development. Discrepancies between perceived and actual impacts of *RML* on agricultural practices were also observed by Fafchamps and Minten (2012).

Table 4-7: Comparison of production increases and price enquiries

	Increase due to *M-Farm* (% of all farmers)		**Send price enquiries** (% of farmers who increased crop due to M-Farm)	
	maize	**beans**	**maize**	**beans**
Rachuonyo	95	65	84	79
Migori	68	36	40	0
Total	87	56	74	69

Number of observations: 115
Source: Compiled from survey data collected by the author

While price information may have encouraged farmers to expand certain crops, it does not seem to have encouraged farmers to introduce new crops. While 45% of farmers in Migori had begun growing a new crop (passion fruit), the decision was likely motivated by farmers' participation in contract farming with EAG rather than price information from *M-Farm*. In Rachuonyo, only a few farmers had begun growing a new crop (3 sweet potatoes and 1 sorghum).

Farmers do not seem to have increased the production of certain crops at the expense of others. Only 3% of farmers in Rachuonyo and none in Migori said that they had decreased production of one or more crops due to using *M-Farm*. It is unclear whether the reported expansion occurred on previously unused land or through intensification.

It is interesting to note that the perceived impact of participation in *M-Farm* has been less pronounced on the production of commercial crops such as maize and beans in Migori compared to Rachuonyo. It may be that offering market connections in the form of contract farming (rather than by expanding marketing choices in general) reduces the impact of price information on production decision because it reduces farmers' incentive to increase other crops. This hypothesis is supported by the finding that Migori farmers less frequently request price information for crops that they sell commercially (i.e. only 22% for maize and 4% for beans, see above). At the same time, the price information may have been used earlier in the decision-making, e.g. when deciding whether to enter into a contract at all and how much of the land to dedicate to the crop under contract and to other commercial crops. The survey does not provide data to substantiate this hypothesis since the farmers had already signed the contracts with EAG at the time of the survey.

In addition to crops, farmers do not seem to have adopted other agricultural technologies to a great extent in response to the price information. However, the adoption of new crops may be part of a stepwise process. Byerlee and Hesse de Polanco (1986), for instance, show that Mexican farmers adopted seeds first, followed by herbicides and then followed by fertiliser.

The study did not differentiate by gender in the analysis of the survey data. However, a gender-related finding from the focus group discussions is worth mentioning. Conversations with women farmers in Rachuonyo indicate that they felt empowered through their participation in *M-Farm*. The training they received on how to use the price information service had familiarised them with use of a mobile phone. Some women also reported that they now owned a mobile phone so that they can use *M-Farm*. Access to the technology and the skill to use it now enables them to also use the mobile phone for other purposes, including conducting business transactions, handling money more securely, communicating with others to obtain information, being contacted to participate in training and calling in case of emergency. In addition, they felt that participation in the programme had improved their social standing in the community because they were now seen to be cleverer (because they know the price of crops) and important (because they are communicating with people from outside).

To better understand the role of *M-Farm* vis-à-vis other measures that could facilitate agricultural technology adoption, the study also assessed the relative importance of price information and market linkages as barriers to adoption. As shown in Figure 4-8, surveyed farmers do not regard these two factors as the main obstacles, although lack of price information is a more important hurdle for farmers in Rachuonyo, cited by 33% compared to 11% in Migori.

Instead, issues related to risk impose more significant constraints on technology adoption in both districts. This finding confirms existing evidence as to the role of risk in preventing technology adoption (e.g. Marra, Pannell, and Abadi Ghadim 2003). Risk of crop losses due to external influences, such as bad weather or crop diseases / pests, were of particular concern to many farmers, especially in Migori. Risk of low performance is not as significant a concern however.

While insurance may help to mitigate risks, 69% of farmers said that lack of access to insurance prevented them from technology adoption. Pilot schemes to offer index insurance to smallholder farmers have been expanding in recent years, in part aided by new ICT trends (Hazell et al., 2010; see also Section 3.1.2). Such schemes can be useful to manage low-to-medium-frequency, covariate risks e.g. drought, pest outbreaks and excess rainfall. With insurance, farmers may be more willing to invest in new technologies while financial service providers or input suppliers may be more willing to offer loans. To what extent existing insurance schemes have indeed changed agricultural production and income has not been empirically assessed (ibid).

Financing was cited as another key barrier to technology adoption. Overall, 69% of respondents said that they did not have the money to purchase technologies. While many farmers in both districts also cited lack of access to credit as an obstacle, the share was more than twice as high in Migori (71% compared to 34% in Rachuonyo). As noted above, access to credit is considerably lower among respondents in Migori than in Rachuonyo.

Figure 4-8: Barriers to adopting agricultural technologies

Number of observations:115
Source: Compiled from survey data collected by the author

Income generation

The price information received through *M-Farm* could generate income gains for farmers in two ways. First, they may be able to receive better prices for their produce (e.g. through bargaining or by choosing a trader with a better offer). Second, different production decisions (e.g. what to grow, how much and which inputs to use, when to harvest) can increase financial returns of agricultural production.

Negotiating better prices

The theoretical literature reviewed above suggests that farmers should be able to bargain for better prices if they have access to price information. Empirical evidence as to the role of m-services in this regard is mixed however. In the case of *M-Farm*, the results are inconclusive. During interviews and focus group discussions, many *M-Farm* users felt they were able to obtain better prices since they began using *M-Farm*. However, results in the survey differed widely depending on the question. When asked whether they had changed the way they sold their crops, only 11% of farmers in Rachuonyo said that they received a better price and none in Migori. However, when asked later in the survey whether price information from *M-Farm* had helped them sell at a better price, almost all respondents agreed.[91] Similarly, when asked whether the information had increased their income, 85% of farmers who were using the price information service answered yes, while 11% said it had not.[92] The differences could be due to the fact that the first was an open question while the second and third were multiple choice (yes/no) questions. The research thus highlights the limitations of relying only on farmers' perceptions to evaluate price impacts. Interestingly, two existing studies showing price gains used surveys (Islam and Grönlund, 2010; Lokanathan et al., 2011) while one study that compared actual prices received did not (Camacho and Conover, 2011).[93]

The possible influence of access to price information on actual prices was also assessed by analysing whether prices for sweet potatoes received by farmers in Rachuonyo had changed since using *M-Farm*. At the time of the survey, farmers in Rachuonyo had been using *M-Farm* for four months on average (omitting those farmers who say that they have used *M-Farm* for more than 18 months), with the majority of responses ranging from one to six months. Thus, for the purpose of the analysis, the price data is divided into two phases: Phase 1 from May until November 2011 when the majority of respondents (72%) had not started using the service ('before *M-Farm*') and Phase 2 from December 2011 until April 2012 when usage increased continuously ('after *M-Farm*').

Figure 4-9 shows sweet potato prices received by the cooperative farmers (using monthly average prices gathered by the coop) and average monthly prices collected by *M-Farm* for sweet potatoes in Nairobi and Kisumu (i.e. the two markets of main interest to the *M-Farm* users in Rachuonyo) between May 2011 and April 2012 (prices deflated using Kenya Food Price Indices). Prices received by Rachuonyo farmers since February 2012 show an upward trend which is more pronounced than price increases in Nairobi and Kisumu. However, even the highest price received after farmers began using *M-Farm* (April 2012) is still lower than in most months prior to using the service. Figure 4-10 presents the difference as a percentage of prices in Nairobi and Kisumu respectively. The figure does not show marked differences between the two time periods. It is important to note, however, that a straightforward comparison between the price trends only provides a very general

[91] One respondent did not answer the question because the crops had not been ready for sale since the household joined *M-Farm*.

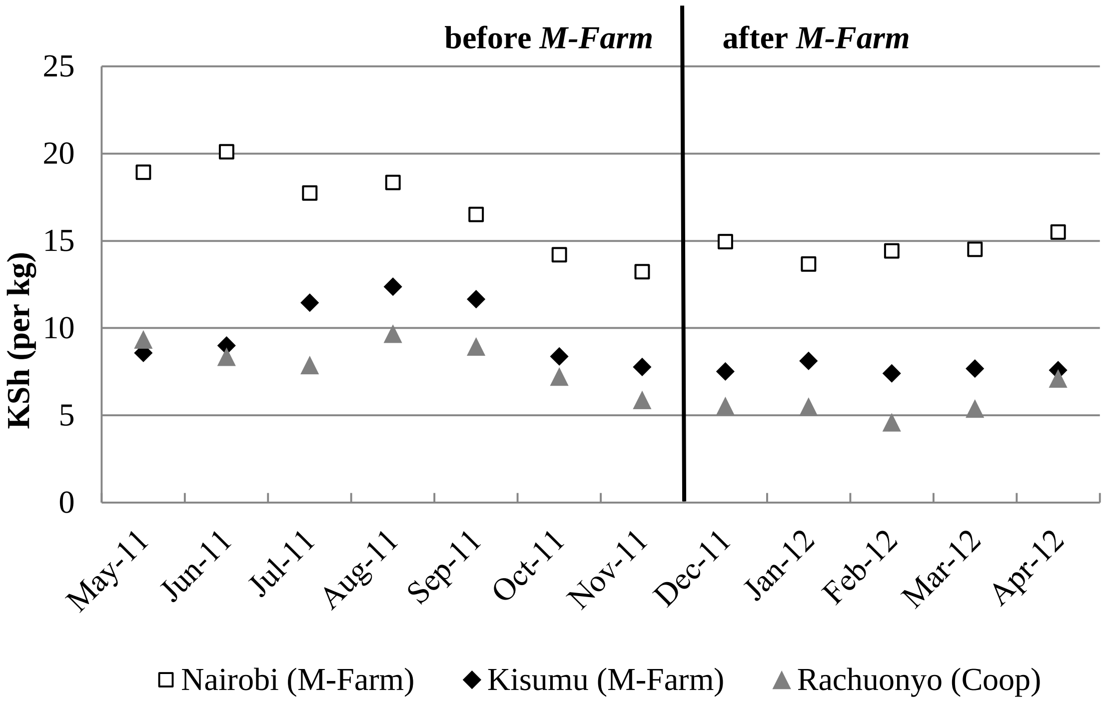
[92] Four respondents had not yet sold crops since starting to use *M-Farm* while one answer was missing.

[93] Studies by Fafchamps and Minten (2012) and Mitra et al. (2013) also do not show price gains, but the studies are not directly comparable since the first does not single out the impact of price information vis-a-vis other types of information while the second does not differentiate between dissemination channels (mobile versus information board).

indication, but may in fact be overly simplistic. Also, the time period for which data are available is too short to provide a definite answer.

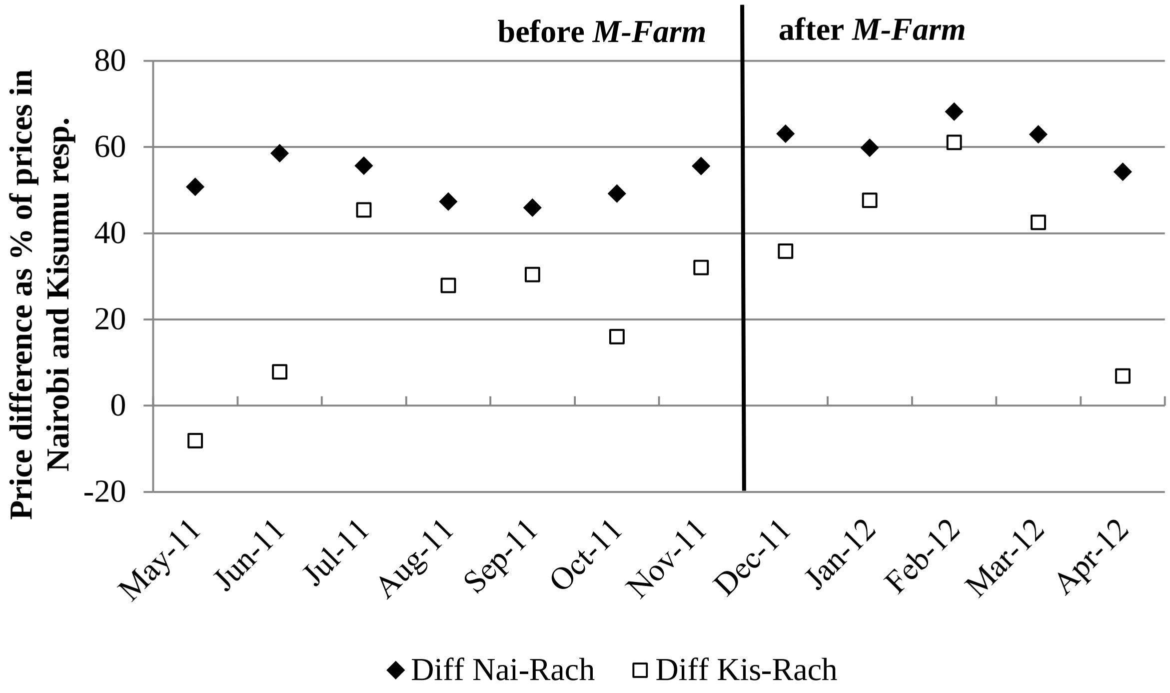
In addition, the comparison in Figure 4-9 shows that the prices received by farmers for their sweet potatoes are mostly lower than the *M-Farm* price reported from the two markets (as would be expected since the buyer has to cover transport and other sales costs). This finding is contrary to the perception of *M-Farm* users on how the price information they receive compares to the sales price. Two thirds of farmers in Rachuonyo stated that they usually sell their produce at around the same price as the *M-Farm* price while 16% said that they receive a higher price. Only 11% noted that they usually sell at a lower price. The distribution of answers is similar in Migori (14% lower, 63% same, 21% higher). These findings also suggest that drawing conclusions on price increases based only on survey results could be misleading.

Figure 4-9: *M-Farm* sweet potato prices and prices received by Rachuonyo farmers



Note: This graph shows average monthly prices for sweet potatoes collected by *M-Farm* in the markets of Nairobi and Kisumu with prices received by sweet potato farmers in Rachuonyo. *M-Farm* prices were provided per 98 kg bag and Nyapalo prices per 165 kg bag. Prices deflated using monthly Food Price Indeces for Kenya from FAOStat (base year 2000 = 100, accessed 6 July 2014).
Data sources: *M-Farm*, Kabonodo Sweet Potatoe Cooperative.

Figure 4-10: Differences between *M-Farm* sweet potato prices and prices received by Rachuonyo farmers



Note: This graph compares the differences between average monthly prices for sweet potatoes in Nairobi and Rachuonyo and Kisumu and Rachuonyo as a percentage of the prices in Nairobi and Kisumu respectively. Prices were deflated using monthly Food Price Indeces for Kenya from FAOStat (base year 2000 = 100, accessed 6 July 2014).
Data sources: *M-Farm,* Kabonodo Sweet Potatoe Cooperative.

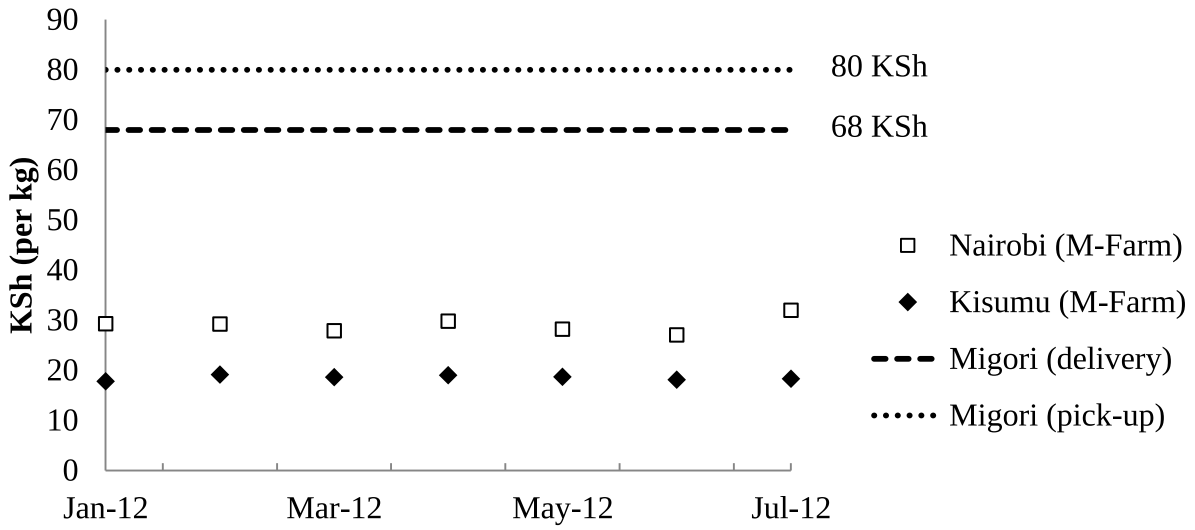
Switching to traders with better offers

With access to price information, farmers may switch buyers because they are better able to assess whether they are being offered a good price. However, in line with findings in Bangladesh (Islam and Grönlund, 2010), the price information seems to have had limited impact on sales patterns among *M-Farm* users. While some farmers, in particular in Migori, said that they had changed their sales patterns since joining *M-Farm*, these changes were attributable to reasons other than price information (i.e. infrastructure and contractual arrangements). Specifically, only 9% of farmers in Rachuonyo stated that they had changed where they sell their produce. Among those, most farmers (67%) said that they are now able to take their sweet potatoes to the collection centres which were set up by ADS. In Migori, a larger share of farmers (45%) stated that participation in *M-Farm* had changed where they sell their produce, but many of them also cited the establishment of collection centres (44%) as well as their links to EAG (39%).

Thus, perceived changes in sales patterns are mainly due to the broader ADS project and the newly established contract with EAG. Farmers did not indicate that the price information had induced them to switch markets or traders. This finding seems to contradict the earlier finding that price and demand information from *M-Farm* plays an important role in farmers' decision who to sell their produce to (Figure 4-4). It may be that the farmers used the information to decide who to sell to among already known traders, rather than selling to new contacts.

M-Farm may also help farmers obtain higher prices for their produce by actively facilitating market linkages with new buyers with better offers. In Migori, *M-Farm* has helped farmers to establish the contract for passion fruit with EAG. A comparison of prices disseminated by *M-Farm* for Kisumu and Nairobi with prices agreed in the contract shows that since farmers started entering contracts with EAG (from January 2012), prices per kg were constantly higher than wholesale prices in Nairobi and Kisumu (Figure 4-11). Farmers also felt that they had gained financially from their participation in the contracts. In the survey, all farmers agreed that the contract had enabled them to obtain a better price for their passion fruits while 90% of farmers said that selling to EAG had increased their income.

Figure 4-11: Comparison of *M-Farm* passion fruit prices and prices received by farmers



Note: This graph compares average monthly prices for passion fruits collected by *M-Farm* in the markets of Nairobi and Kisumu with prices received by farmers in Migori who sell to EAG under contract . *M-Farm* prices were provided per 57 kg bag. Prices deflated using monthly Food Price Indeces from FAOStat (base year 2000 = 100, accessed 6 July 2014).
Data sources: *M-Farm*, EAG contract.

Changes in cropping pattern

Perceived income gains among *M-Farm* users may in fact be attributable to changes in production rather than price gains. For instance, income may increase when farmers switch to crops that generate higher returns or improve their production process. While it is difficult to quantify these impacts on income, some of the findings presented above provide an indication where farmers are likely to have benefitted. Thus, farmers in both districts stated that they had expanded production of certain crops in response to the price information, presumably because they found that they could get higher returns. Also, in particular farmers in Rachuonyo also enquired about prices before harvesting which would enable them to determine the most lucrative time to harvest.

In Migori, farmers noted that the contract with EAG had brought other benefits in addition to improved prices which had impacted production costs and income. Farmers said that the agreed price offered them better and more stable returns than fluctuating market prices, thereby reducing market uncertainties. In the survey, 97% of farmers stated that they were now able to sell their passion fruits faster and thereby reduce spoilage. In addition, delivery to centralised collection points had lowered transportation costs. Payment of the farmers (managed by *M-Farm*) also tends to be faster than when selling to local traders. In the focus group discussions and during interviews, farmers also highlighted the (perceived) importance of *M-Farm* as a mediator and their role in establishing and maintaining trust between EAG and the farmers.

Relative role of mobile phones in delivering price information

Prior to using *M-Farm,* middlemen, buyers in the market and the radio were the main sources of price information among farmers (Table 4-8). In particular the importance of buyers in the market has dropped considerably with the introduction of *M-Farm*. Middlemen continue to be a source of price information for almost half as many farmers while a third still obtains price information from the radio (compared to 42% before *M-Farm*). Trends in the two districts are similar.

Comparing different information sources, radio, TV and newspaper are often judged to be equally good sources of information as *M-Farm* while price information from other sources, including middlemen, are mainly seen as worse (Table 4-8). The TV and the newspaper are not commonly used as price information sources, however (even though 31% of respondents have access to a TV).

The survey data suggests that the radio offers a viable alternative to disseminating price information to *M-Farm* in the early stages of production, but *M-Farm* becomes more important closer to the selling stage (Figure 4-12). This is particularly true in Migori where twice as many farmers obtain their price information from the radio to decide which crops to grow while over five times as many indicated *M-Farm* as their source of information compared to the radio. Farmers tend to cite either radio or *M-Farm* as their source of price information, but rarely both.

It may be that in the early stages of the production process price information is not as time-sensitive and farmers may wait for price updates that they can receive for free via the radio.[94] When selling crops, however, the timeliness of the information becomes more important and farmers may be more willing to pay for the additional benefit of information on demand from *M-Farm*. Also, farmers are able to store and access the SMS from *M-Farm* when needed. This hypothesis is also supported by the qualitative data. During interviews, some farmers noted that *M-Farm* was particularly useful because they could obtain the information when needed and did not have to wait for the radio programme.

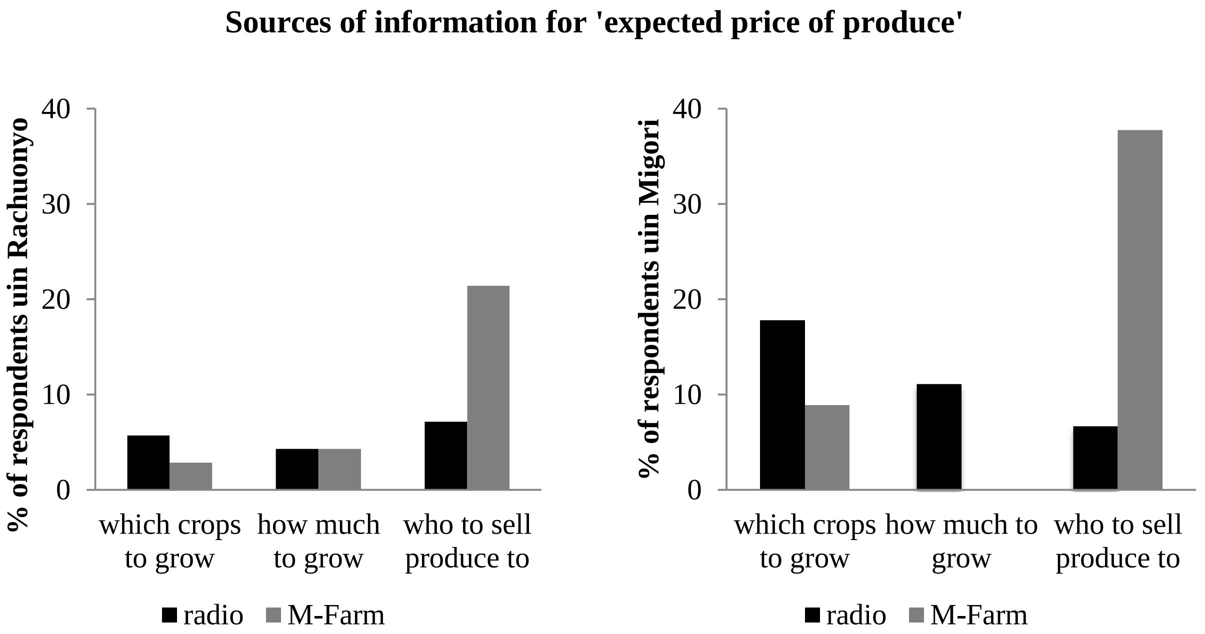
[94] Radios are widely available among the respondents; the majority either owned (94%) or used someone else's radio (1%).

Table 4-8: Other sources of price information before and since using *M-Farm*

	Source of price information*		Price information from *M-Farm* is … than price information from… **		
	before	now	better than	as good as	no answer
middlemen	50	23	40	3	57
buyers in the market	35	6	20	0	80
info board in village	3	1	25	0	75
info board in market	8	3	33	0	67
info board in gov. offices	3	0	100	0	0
extension agent	2	1	33	0	67
radio	42	33	24	35	41
TV	4	2	14	14	71
newspaper	3	1	0	33	67

* % of respondents
** % of respondents who said that they had used and/or continued to use the respective information source. Missing answers are factored into the calculation of percentages.
Number of observations: 115
Source: Compiled from survey data collected by the author

Figure 4-12: Comparison of the radio and *M-Farm* as price information sources by district

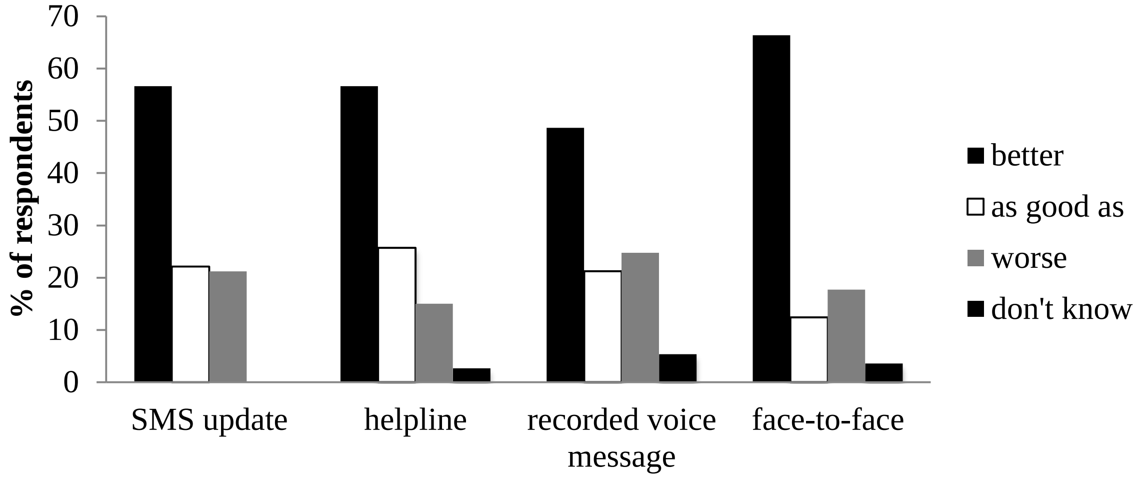


Number of observations: 115
Source: Compiled from survey data collected by the author

The survey and anecdotal evidence also show that some farmers would value a more interactive channel to access price (and other) information. Two thirds of the respondents would prefer to receive the information through face-to-face contact rather than by sending an SMS (Figure 4-13). Regular SMS updates and a helpline were the second most popular options (57%). Responses may have differed, however, if the options had been associated with a particular cost. For instance, when focus group participants were asked whether they would prefer regular updates, they said that it would depend on the cost. The focus groups discussions and interviews with farmers highlighted some of the reasoning behind the preferences:

- The advantage of a helpline and face-to-face contact is that one can interact and ask questions.
- The disadvantage of face-to-face communication is that people are widely dispersed and disseminating information to everyone would be impractical.
- The concern with a helpline was that it may only be available in two languages (English and Swahili) and therefore not accessible to those who speak other languages.
- The advantage of regular updates is that the farmers would not be required to have credit on their phone.

Figure 4-13: Alternative delivery channels for accessing price information from *M-Farm*



Number of observations:113
Source: Compiled from survey data collected by the author

Information sharing among farmers was also found to be an important dissemination channel. 81% of farmers who use *M-Farm*'s price information service say that they share the price information they receive with others (79% in Rachuonyo and 84% in Migori). Sharing is not only confined to the group (with whom 38% share price information), but also includes other farmers (62%).

M-Farm users

This section describes the characteristics of *M-Farm* users, looking both at households that have access to *M-Farm* prices and individual users who send price enquiries to *M-Farm*. Where available, data gathered in the survey are compared with district averages, obtained from the Kenya Integrated Household Budget Survey 2005/2006, the Census 2009 and the ICT survey 2010 (whichever has the most recent data). The comparison is used to assess who is being reached by *M-Farm* by examining the representativeness of *M-Farm* users and households compared to average residents in the two districts.

All surveyed households in Rachuonyo access price information through *M-Farm*. In Migori, four households do not use the price information service while two households had not signed a contract with EAG to sell passion fruits.

Characteristics of households using M-Farm

On average, the surveyed households using *M-Farm* are better-off than average households in the two districts (Table 4-9). A larger share of households owns and rents land and holding sizes are 50% larger. Houses are similarly built as the average, but tend to be larger in terms of room number. Poverty rates (as measured by yearly income) among respondents are also lower than district averages (Table 4-9). In Rachuonyo, 14% of respondents reported income levels[95] below the national poverty line[96] while 13% did so in Migori, compared to just over 40% district average. Yearly income levels of the two groups of farmers are comparable at around KSh 120,000. However, reported income data should be read with some caution since many farmers find it difficult to estimate their yearly income.

Regarding ICT ownership, mobile phones and radio are particularly common among the respondents (Table 4-9). 73% of respondents in Rachuonyo and 87% in Migori own a mobile phone – 20% and 40% more than district averages respectively. Radio is very widespread in both districts where more than 90% of households own a radio. In Rachuonyo, TVs are less common than the average, but considerably more households have access to the internet (14% compared to an average of 2%). In contrast, none of the households in Migori had access to the internet.

Data on access to credit among surveyed households in Rachuonyo and Migori shows the opposite trend to district averages (Table 4-9). Only 24% of respondents said they had received credit in Migori compared to a district average of 60%. In Rachuonyo, 57% of surveyed households had received credit, 20% more than the average. The main sources of credit in Migori are banks and women's groups while respondents in Rachuonyo obtained credit mainly from community and farmers' groups and to a lesser extent from banks and women' groups. Only one farmer in the survey had obtained insurance.

Maize and beans are the most commonly grown crops in both districts, often through intercropping (Table 4-10). Almost all farmers said that they grew maize (slightly higher than the average) and close to two thirds also grow beans, roughly twice as many as the district averages. In particular the widespread production of beans, which are commonly sold on the market, could indicate a greater market orientation of surveyed farmers than the average farmer in the two districts.

Livestock ownership rates also point to a greater wealth of surveyed farmers (Table 4-10). For almost all types of livestock, ownership rates were higher than average, including cattle which are more expensive to purchase than e.g. chicken.

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[95] Respondents were asked to estimated how much income the household earns from selling crops (in KSh per year) and how much they earn from other sources of income (in KSh per year). Total annual income was estimated by adding farm and off-farm income.

[96] The national poverty line in rural areas was KSh 18,744 per year in 2005/2006 when the data for the KIHBS was collected. The rate was adjusted to 2011 prices based on annual inflation rates and using 2005 as the base year. The calculated poverty line is KSh 11,531 per year.

Table 4-9: Comparison of housing characteristics and asset ownership

		Rachuonyo survey*	Rachuonyo**	Migori survey*	Migori**	Data source
Land	owns land %	**98.6**	85.9	**100**	72.4	KNBS (2006)
	rent/lease %	**48.6**	8.8	**40.4**	22.4	KNBS (2006)
	holding size (acres)	**3.2**	2.4	**3.3**	2.2	KNBS (2006)
Walls	stone		2.1		0.8	Census 2009
	brick/block	**15.7**	7.8	**8.5**	11.6	Census 2009
	mud/wood	**72.9**	72.8	**78.7**	69.3	Census 2009
	mud/cement	**11.4**	16.2	**12.8**	16.3	Census 2009
	wood only		0.4		0.5	Census 2009
	corrugated iron		0.4		1.1	Census 2009
	other		0.0		0	Census 2009
Roof	corrugated iron	**96**	89.3	**100**	93	Census 2009
	tiles		0.6		0.9	Census 2009
	concrete		0.0		0.5	Census 2009
	asbestos		1.4		2.2	Census 2009
	grass	**4.3**	8.5	**0**	3.2	Census 2009
	makuti		0.1		0.1	Census 2009
	tin		0.1		0.1	Census 2009
	mud/dung		0.0		0.1	Census 2009
Rooms	1	**1.4**	9.9	**2.1**	22.5	KNBS (2006)
	2	**37.1**	54.9	**12.8**	36.4	KNBS (2006)
	3	**41.4**	25.2	**55.3**	24.7	KNBS (2006)
	4-5	**17.2**	7.8	**21.3**	12.8	KNBS (2006)
	6-10	**2.9**	2.2	**8.5**	3.6	KNBS (2006)
Lighting fuel	firewood	**0**	2.4	**0**	1.7	KNBS (2006)
	Grass	**0**	0.0	**0**	0.0	KNBS (2006)
	Paraffin	**87.1**	97.1	**100**	95.2	KNBS (2006)
	electricity	**2.9**	0.5	**0**	2.5	KNBS (2006)
	Solar	**10**	0	**0**	0	KNBS (2006)
	Gas	**0**	0	**0**	0.7	KNBS (2006)
Poverty rate		**16.4**	40.5	**24.4**	42.5	KNBS (2006)
ICT	Landline	**0**	0	**0**	0.2	ICT survey 2010
	computer	**2.9**	2.2	**0**	2.9	ICT survey 2010
	Internet	**0**	2.6	**14.3**	1.9	ICT survey 2010
	Radio	**92.9**	75.6	**95.7**	69.7	ICT survey 2010
	TV	**22.9**	22.6	**14.9**	21.4	ICT survey 2010
	mobile phone	**87.1**	47	**73.3**	53.2	ICT survey 2010
Credit	Access	**57.1**	37.1	**24.4**	60.3	KNBS (2006)

Data sources: * survey results compiled by the author (no. of obs.: 115); ** as indicated in the last column.

Table 4-10: Comparison of crop and livestock production

		Rachuonyo survey*	Rachuonyo**	Migori survey*	Migori**
Crops	Maize	**97.1**	91.4	**100**	94.8
	Sorghum	**11.4**	62.4	**6.3**	27.6
	Cassava	**10.0**	6.6	**14.9**	19.3
	sweet potatoes	**80.0**	24.5	**34.0**	10.6
	potatoes	**0**	0.7	**2.1**	0
	beans	**62.9**	35.7	**63.8**	29.2
	bananas	**20.0**	0	**40.4**	2.9
Livestock	Cattle	**77.1**	56.5	**76.6**	64.7
	Sheep	**28.6**	19.8	**14.9**	14.7
	Goats	**55.7**	45	**34.0**	39.7
	Chicken	**94.3**	85.5	**97.9**	84.5
	Donkeys	**8.6**	3.1	**0**	3.4

Data sources: * survey results compiled by the author (no. of obs.: 115); ** KNBS (2006).

Characteristics of M-Farm users

In most cases, the survey respondents were also the ones who send the SMS for price enquiries to *M-Farm* (93% in Rachuonyo and 83% in Migori). In the majority of households, only one person sends the SMS (83% in Rachuonyo and 73% in Migori). Others include family members (in particular the spouse) and in some cases coop members. This section summarises the characteristics of the respondents who send the SMS themselves.

The two groups of farmers in Rachuonyo and Migori are broadly comparable in terms of personal characteristics (Table 4-11). Surveyed *M-Farm* users in Rachuonyo included a larger share of men, but the share of household heads was comparable between the two districts. The average age of *M-Farm* users in Rachuonyo was 40 (ranging from 21 to 76) and 48 in Migori (27 to 70). Respondents in Rachuonyo had spent 17 years farming on average while Migori users had spent 21 years.

Table 4-11: Personal characteristics of *M-Farm* users

(%)		Rachuonyo	Migori
Gender	male	45	59
	female	55	41
Household head	yes	62	65
	no	38	35
Relation to household head	spouse	35	32
	child	3	0
	sister-in-law	0	3

Note: The table shows proportions of respondents who send SMS to *M-Farm* themselves rather than someone else in the household.
Number of observations: 99
Source: Compiled from survey data collected by the author

Education levels among respondents are also comparable between the two districts and generally higher than district averages (Table 4-12). A (slightly) larger share of respondents in Rachuonyo had attended secondary school or college than in Migori, but a larger number also had not attended school (all women). Attendance rates for secondary and tertiary education are considerably higher among *M-Farm* users than district averages.

Table 4-12: Education level of *M-Farm* users

	Rachuonyo survey*	Rachuonyo**	Migori survey*	Migori**	Data set (KNBS)
Primary	**47.7**	83.8	**58.8**	84.2	Percentage distribution of Population (3+ years) by Highest School level reached and region
Secondary	**43.1**	17.2	**38.2**	18.7	
Tertiary	**4.6**	0.7	**2.9**	1.0	
None	**4.6**	5.9	**0.0**	4.3	

Data sources: * survey results compiled by the author (no. of obs.: 115); ** KNBS (2006)

M-Farm users in Rachuonyo tend to have access to better equipped phones than in Migori (Table 4-13)**.** In Rachuonyo all *M-Farm* users own at least one and in some cases even two phones while in Migori, 18% do not own a phone, but use someone else's. Rachuonyo farmers also own phones with more functions, such as a colour screen or radio. In general, however, a large share of farmers in both districts own phones with no additional functions (45% in Rachuonyo and 59% in Migori). The preferred network in both districts is Safaricom and only a few respondents use Airtel or Yu. Almost all respondents who own a phone charge it at the recharge shop.

Table 4-13: Phone characteristics of *M-Farm* users

(%)		Rachuonyo	Migori
Phone ownership	None	0	18
	1 phone	92	82
	2 phones	8	0
Networks	Safaricom	100	82
	Airtel	6	3
	Yu	3	3
Battery charging	recharge shop	94	79
	solar panel	2	0
	electricity	0	0
	not specified	5	3
	no phone	0	18
Phone functions	colour screen	37	15
	internet	20	3
	Email	15	3
	camera	18	3
	Radio	37	21
	music player	18	3
	none	45	59

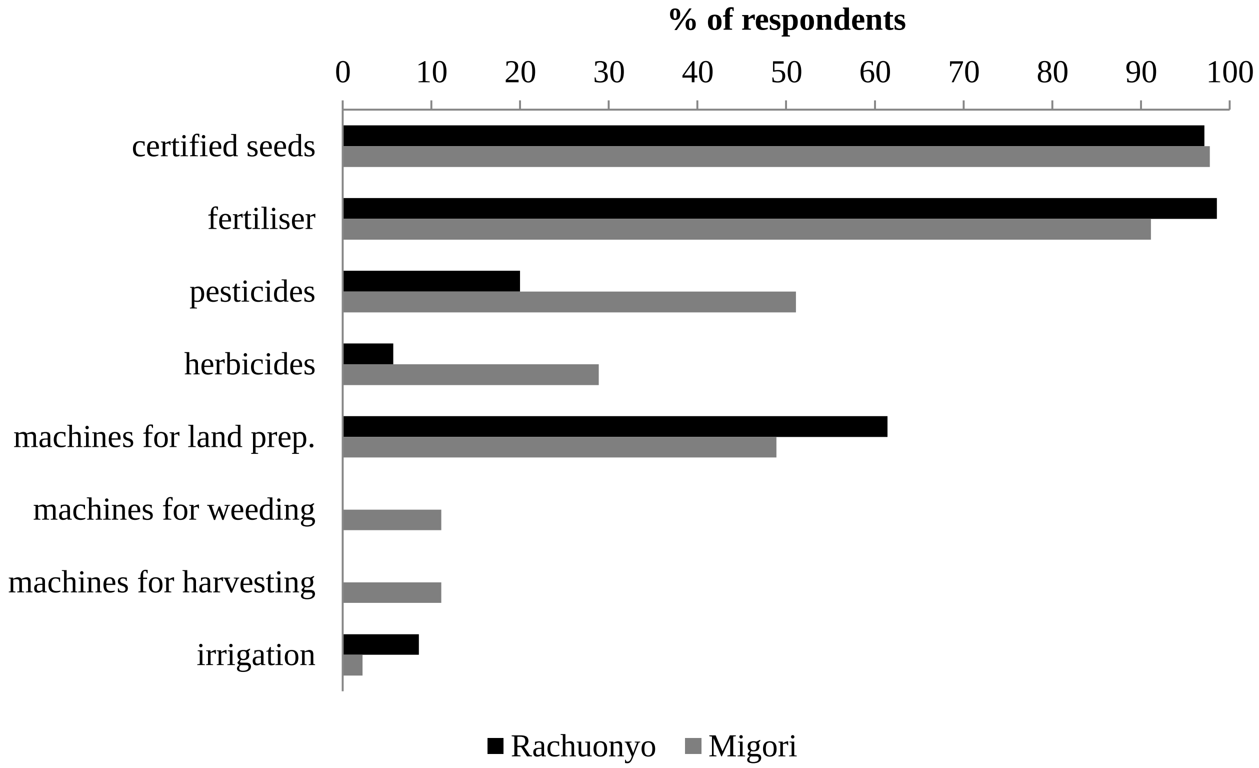
Note: The table shows proportions of respondents who send the SMS to *M-Farm.*
Number of observations: 99
Source: Compiled from survey data collected by the author

Current access to and demand for agricultural technologies

Surveyed households have limited, but nevertheless better access to agricultural technologies compared to average households in the two districts (Figure 4-14, Table 4-14). Most farmers, in particular in Rachuonyo, apply fertiliser (mainly inorganic). The shares of fertiliser users is higher than district averages, with 91% in Migori (compared to a district average of 65%) and 99% in Rachuonyo (compared to 50%). Although use of irrigation is low in both districts, it is still higher than district averages. In Migori, 2.2% of farmers used irrigation (3.2% average) while in Rachuonyo 8.6% used irrigation compared to 0.4% on average. Only two farmers used a pump while the rest (4) used watering cans.

In terms of other agricultural technologies, almost all households use certified seeds, although only for maize. Pesticide and herbicide use is more widespread in Migori where just over half the surveyed farmers use pesticides (20% in Rachuonyo) and 29% herbicides (6% in Rachuonyo). Machines for land preparation (oxen) are also frequently cited. In both districts, the majority of farmers state that they practice crop rotation (95%) and use conservation methods (91%).

Figure 4-14: Current use of agricultural technologies



Number of observations:115
Source: Compiled from survey data collected by the author

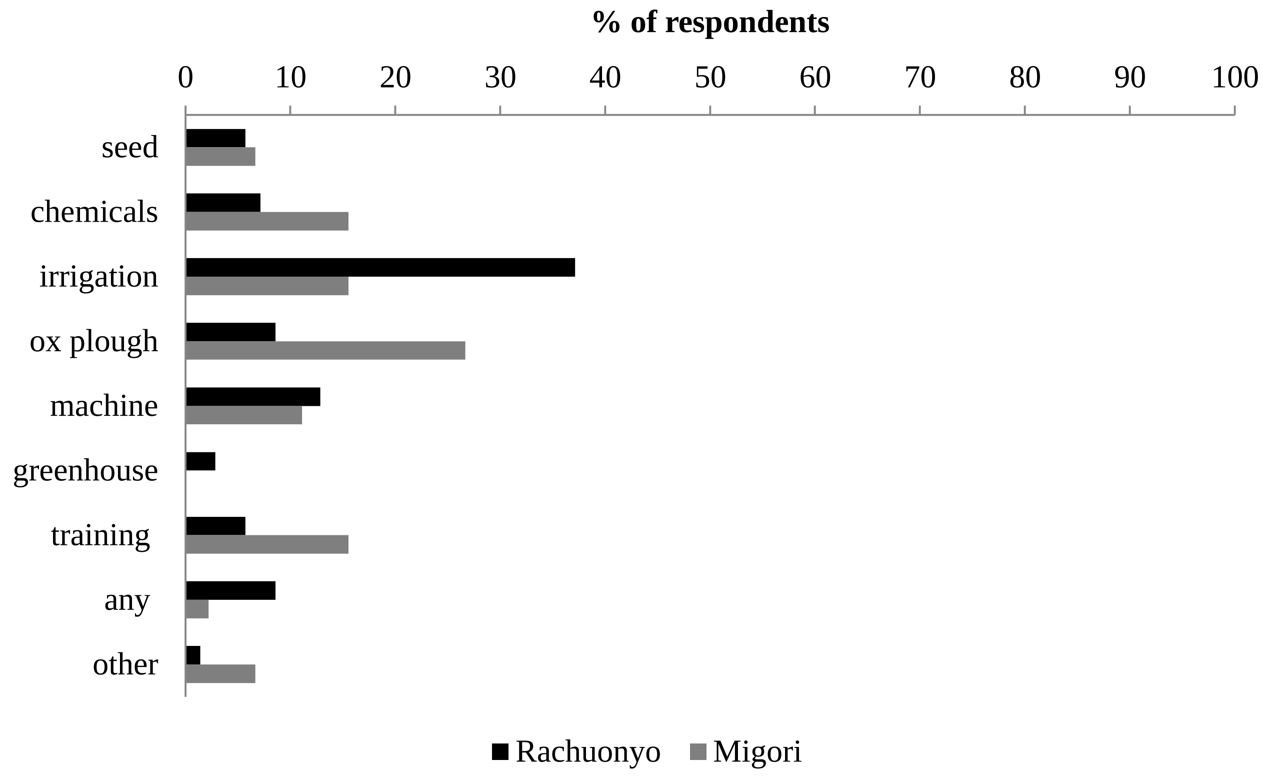
Table 4-14: Comparison of access to agricultural technologies

		Migori survey*	Migori**	Rachuonyo survey*	Rachuonyo**
Irrigation	have access	**2.1**	3.2	**8.6**	0.4
	water pump	**0.0**	3.2	**4.3**	0.4
Fertiliser	any	**91.1**	64.6	**98.6**	50.1
	Inorganic	**95.1**	95.7	**100.0**	29.8
	Organic	**9.8**	25.5	**0.0**	26.0
	Unknown	**0.0**		**1.5**	

Data sources: * survey results compiled by the author (no. of obs.: 115); ** KNBS (2006).

Overall, demand for technology is relatively low, even for technologies that are not widely used. Thus, while irrigation is the most sought after technology in Rachuonyo, only 37% of respondents would like to have access to irrigation technologies although just 9% currently use it (Figure 4-15). The discrepancy is even more apparent in Migori where only 16% of surveyed farmers are interested in irrigation technologies while 2% currently use it. Interest in ox ploughs is high in Migori, as well as chemicals and training. Demand for certified seeds is low in both districts even though for now farmers only use certified maize seeds.

Figure 4-15: Demand for other agricultural technologies



Number of observations:115
Source: Compiled from survey data collected by the author

Market access and participation

Almost all farmers sell a sizeable share of their produce.[97] Maize and beans are most widely sold in both districts. Of the farmers who grow maize, 81% also sell maize in Rachuonyo and 71% in Migori. In the case of beans, close to two thirds of respondents in Rachuonyo and 43% in Migori sold the beans they grew. A significant share of sweet potato growers sold their crop in Rachuonyo (84%) while close to 90% of passion fruits being grown was sold in Migori. Respondents also sell numerous other crops, but the shares are less significant.

On average, surveyed farmers live closer to markets than average communities in the district (Table 4-15). In both districts close to a third of farmers live 1 km or less away from a market while hardly any households are so closely located on average. The difference to district averages is particularly pronounced in Rachuonyo where the majority of average households (81%) have to travel more than 5 km to the nearest market while just less than half of surveyed farmers have to travel such long distances.

Table 4-15: Comparison of distance to market (% per district)

	Migori survey*	Migori**	Rachuonyo survey*	Rachuonyo**
< or = 500m	**20.0**	0	**20.0**	0
500m-1km	**11.1**	2.4	**8.6**	0
1,1-2,9 km	**24.4**	25.8	**14.3**	0
3-4,9 km	**13.3**	16.2	**8.6**	19.2
5 km or more	**31.1**	55.7	**48.6**	80.8

Data sources: * survey results compiled by the author (no. of obs.: 115); ** KNBS (2006).

In summary, surveyed households are more likely to grow commercial crops (especially beans) compared to average farmers, they sell a large share of the crop and live closer to markets than average households in the district. These findings suggest that the surveyed farmers are more commercially oriented than average farmers in the two districts.

Mobile phone usage among M-Farm users

All respondents have access to a mobile phone. Most of them own a phone (97% in Rachuonyo and 80% in Migori) while the remainder uses someone else's (primarily family members). These rates are considerably higher than the district averages in 2009 when only around 40% of respondents owned a mobile phone (Table 4-16).[98] A sizeable proportion also lets others use their phone (40% in Rachuonyo and 33% in Migori), in particular family members.

[97] One respondent in Rachuonyo had only recently started growing maize, beans and sweet potatoes, but had not yet sold the harvest.
[98] Calculation of the authors using Finaccess 2009 data.

Table 4-16: Mobile phone access and use

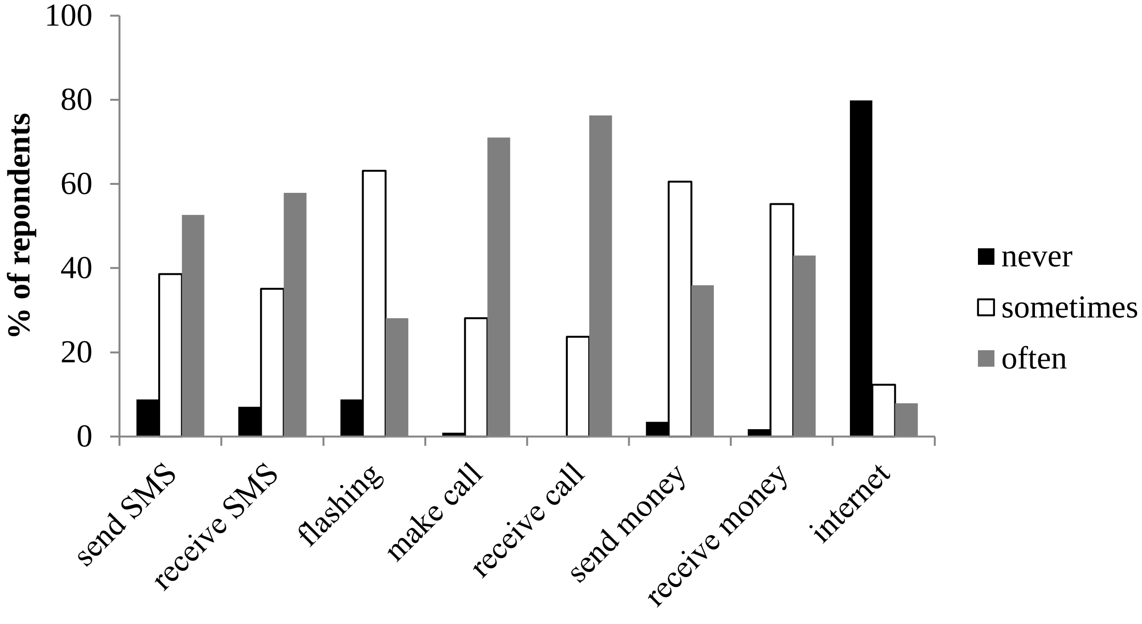
		Rachuonyo survey*	Rachuonyo**	Migori survey*	Migori**
Access to a mobile phone	own a phone	**97.1**	38.9	**80.0**	41.8
	share a phone	**2.9**	48.1	**20.0**	42.9
	no access	**0**	13.0	**0**	15.3
Send SMS	yes	**98.6**	31.5	**79.5**	36.7

Data sources: * survey results compiled by the author (no. of obs.: 115); ** calculated by the author using Finaccess 2009 data

In general, *M-Farm* users who own a mobile phone send price enquiries more frequently than those who have to use someone else's phone. Thus, 41% of respondents who own a phone send biweekly price enquiries compared to 13% who share a phone. In contrast, 63% of respondents who share a phone requested price information once a week compared to 44% of phone owners. However, the sample of *M-Farm* users without a phone was small (6 respondents) and the answers may not be representative.

Mobile phones are mostly used to make and receive calls, but use of the phone to send and receive SMS is also common (Figure 4-16). Usage of SMS is much higher than district averages in 2009 (Table 4-16). Respondents only use their phone sometimes for flashing and receiving and sending money while hardly any respondent uses the internet. The main reasons cited for not using a particular mode were that the phone lacked the necessary feature (59%) and/or that the respondent did not know how to use the mode (11%).

Figure 4-16: Modes of mobile phone use



Number of observations: 114
Source: Compiled from survey data collected by the author

Summary of Key Findings

The role of M-Farm in adoption decisions and income generation

The surveyed farmers are using price information to plan production processes when deciding what to grow, when to harvest and who to sell to. While most enquiries are sent at the sales stage, farmers also request price information at earlier stages of production. Information about demand is generally seen as more important for decision-making than price information.

Many farmers report that the use of *M-Farm* had encouraged them to change their cropping patterns by expanding certain crops, but less so to introduce new crops. Comparing reported production changes and price enquiries by crop, however, suggests that farmers may have overestimated the role of *M-Farm*.

In Migori, fewer farmers felt that price information from *M-Farm* had impacted the production of maize and beans than in Rachuonyo. Engaging in contract farming may in fact have provided a disincentive for farmers to adjust their cropping pattern to price signals because farmers focused more attention on servicing the contract.

The price information does not seem to have induced farmers to change traders on a large scale. Instead, changes in sales patterns since joining *M-Farm* were mainly attributable to reasons other than price information (e.g. because farmers now sell at collection centres and under the EAG contract). While the collaboration with *M-Farm* has enabled farmers to access a new buyer (EAG) in Migori, the arrangement did not establish contact or sales relationships with other buyers beyond EAG either for passion fruit or for other produce.

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 do 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.

In Migori, farmers reported that the contract with EAG had brought financial benefits. Since farmers started entering contracts with EAG (from January 2012), the contractually agreed price of passion fruits sold to EAG was consistently higher than wholesale prices in Nairobi and Kisumu.

Women farmers in Rachuonyo felt empowered through their participation in *M-Farm* because they were trained on how to use a mobile phone, had better access to a mobile phone to use *M-Farm* and enjoyed a higher social standing because of their knowledge of prices and participation in the project.

Relative role of mobile phones in delivering the service

Prior to using *M-Farm*, middlemen, buyers in the market and the radio were the main sources of price information among farmers. Since using *M-Farm*, many farmers continue to obtain price information from middlemen, but less so than before.

The radio, TV and newspaper are often judged to be equally good sources of information as *M-Farm* while price information from other sources, including middlemen, are mainly seen as worse. The radio offers a viable alternative to *M-Farm* in disseminating price information in the early stages of production, but *M-Farm* becomes more important closer to the selling stage.

Sharing of price information among farmers is another important dissemination channel. Some farmers would also value interactive channels of communication to obtain additional information.

M-Farm users

Surveyed households are generally better-off than average households in the districts, measured for instance with regard to rates of land ownership and rental, holding sizes, number of rooms in the house, poverty rates, ICT ownership and livestock ownership. Their average level of education is higher than district averages, especially with regard to secondary and tertiary school attendance rates.

Surveyed households have limited, but nevertheless better access to agricultural technologies than average households in the two districts. Certified seeds are widely used, but only for maize production. Fertiliser and oxen are also fairly common. Overall, demand for technology is relatively low, even for technologies that are not widely used.

The main barriers to technology adoption are the perceived risk of crop losses due to external influences, such as bad weather or crop diseases / pests, and lack of insurance to mitigate the risks, lack of money or credit to purchase the technologies, labour availability and soil quality. Lack of information about potential buyers or prices are not seen as the main obstacles (although more so in Rachuonyo).

Surveyed households are more likely to grow commercial crops (especially beans) compared to average farmers in the two districts, they sell a large share of the crop and live closer to markets than average households. These findings suggest that the surveyed households are more commercially oriented than average farmers.

All respondents have access to a mobile phone and most of them own one. Phone ownership is higher in Rachuonyo where many farmers also have access to better equipped phones than in Migori (although the phones used in both districts are basic with few if any additional features). Phone owners enquire more frequently about prices than those who use someone else's phone.

4.5 Success Factors

Since its inception in October 2010, *M-Farm* has continued to expand in terms of staff, funding and functionalities. The service is very well regarded among the *M-Farm* users in the two study sites. It has also received extensive publicity internationally as an example of a successful start-up. A number of factors have contributed to the company's progress related to the company itself, the *M-Farm* users and the Kenyan context.

M-Farm team

M-Farm offers a value to users, in particular through the combination of price information and marketing services. As Jamila Abassa notes, "information alone isn't enough. Information needs execution – without that you're not changing anyone's life" (cited in Kimo, 2011). The survey also shows that the perceived benefits of *M-Farm* are often attributed to the package of services (even if some of those services are in fact provided by ADS rather than *M-Farm*).

The company has greatly benefited from the dedication of the *M-Farm* team. The members of the team are committed to *M-Farm* full-time, are permanently reachable by phone for farmers, buyers and local partners, and often spend evenings and weekends in the office.[99]

The company is able to present itself well externally through its professional website and convincing presentations of the company that convey the aim and dedication of the *M-Farm* team. This has helped to raise awareness of the company within and outside Kenya and attract interest among investors. [100]

The company has managed to keep its focus as it evolved. While details of the business plan changed, the three broad ideas (group selling, group buying and price information) remained unchanged. The *M-Farm* team appreciates that farmers face a wide range of challenges, but as technology experts, their focus should be on addressing those problems that lend themselves to ICT solutions.[101]

While retaining the broad focus, *M-Farm* has also been able to adapt details of the business plan to changing circumstances and farmers' needs. Initial ideas were and continue to be adjusted in response to ground-truthing with potential users and business partners, including spending a month with farmers in Kinangop in the early stages of operation and regularly visiting project partners and farmers in the field sites. The team also met with other stakeholders at the outset, including seed and fertiliser suppliers and produce buyers to identify potential partners. Their close collaboration with local partners, including regular visits to their areas of operation, has also enabled them to better understand the local context and adjust to feedback from the partners.

The *M-Farm* team has managed to establish trust with the famers, both personally through frequent visits and by working with trusted local partners. The quality and timeliness of the price information has also helped to build trust in the service. In Migori, *M-Farm* plays a vital role in establishing trust between the farmers and the buyer (EAG) by facilitating (what farmers perceive to be a fair) contract and continuing to function as an arbitrator and mediator. This trust between buyers and sellers plays a critical role in establishing business transactions with the help of ICTs (e.g. Molony 2006; Resnick et al. 2003).

In Rachuonyo and Migori, *M-Farm* can capitalise on the structures that are being set up by ADS which have helped to organise farmers in groups, train them in agribusiness skills and establish supply chains for sweet potatoes and passion fruit. Several studies conclude that farmers who are part of a group are more likely to use and benefit from market information (Ferris and Robbins, 2004; Kiiza and Pederson, 2012). These structures are also important to link farmers with buyers by ensuring that the produce can be delivered in time and with the required quality. The SMS-service is then used to facilitate the delivery of produce through existing structure. As Boyera (2012) notes, "[m]aking a structure in

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[99] Susaneve Oguya, *M-Farm,* pers. comm. 1 May and 7 June 2012.

[100] For instance, techfortrade decided to invest in the company after seeing the company's presentation at the Pivot 25 competition in 2011. The company has also been featured in various websites and reports as an example of a successful m-service (e.g. Andres, 2012; Ekiru, 2011; Jackson, 2012; Kimo, 2011; Mulupi, 2011; World Bank, 2011). The company was also named by infoDev as a Top 20 Access to Market and Finance selectee (Vasdev, 2012).

[101] Angela Crandall, iHub Research, pers. comm. 18 May 2012.

place more efficient with new tools like mobiles is far far far easier than changing or setting-up a new structure".

M-Farm users

As elaborated in Section 4.4.2, *M-Farm* users share certain characteristics that make it easier to market an SMS-based price information service to them:

- Education levels among the surveyed *M-Farm* users are high. Almost all of them have at least attended primary school and over a third has also attended secondary school.
- All surveyed users either own a mobile phone or have access to someone else's.
- Most respondents use their phone to send and receive SMS (either sometimes or often). While it is not clear whether some may have started using SMS because of *M-Farm*, the fact that 40% send and receive SMS frequently suggests that SMS use is also common for purposes other than *M-Farm*.
- Farmers in Rachuonyo and Migori are already organised and market-oriented. Especially farmers in Migori are keen to take on new ideas (passion fruit as well as other crops) and may therefore be more open to engaging with new ICT solutions.

ICT ecosystem in Kenya

M-Farm is also able to benefit from Kenya's ICT ecosystem (as described in Section 3.2). Participation in competitions, for instance, has greatly helped *M-Farm* in particular in the early stages. *M-Farm* was able to fine-tune their business plan in response to advice during the IPO48 competition. During a 14-day pre-stage, the business ideas are posted online and advisors challenge the entrepreneur to help them turn the idea into a business. According to the organisers: "This transparent approach will quickly show whether the entrepreneur has the ability to sell his idea, debate it, and pick out relevant information from the process" (ICT4Entrepreneurship, 2010). As a result, *M-Farm*'s initial ideas where further narrowed down over the course of the competition. [102]

Competitions have also provided *M-Farm* with a useful platform for fundraising. As Jamila Abass notes:

> During the competition process you learn new things that are very helpful. You may receive mentorship and coaching. It gives you an opportunity to see your idea through other people's eyes. And if you win and get a cash prize, then you get capital to start. The networking and publicity is also a plus. (cited in Ekiru, 2011)

The price at the IPO48 competition provided the seed funding to start the company. *M-Farm* has also taken advantage of the free publicity, exposure and marketing for the company offered by competitions (Kimo, 2011). At the Pivot 25 competition in Nairobi in June 2011, for instance, the *M-Farm* presentation caught the attention of techfortrade's Chief Executive William Hoyle who subsequently decided to invest in the company. In addition to financing, techfortrade has also supported *M-Farm* through capacity building.

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[102] Different versions of the pitch are available at www.humanipo.com/M-Farm.

M-Farm has also been able to take advantage of the expanding ICT infrastructure for local start-ups. The company started out at the iHub, later secured an office at the m:lab and then moved to offices in the same building that also houses the iHub and m:lab, thereby profiting from subsidised physical space, infrastructure, mentorship and connections to other developers and investors.

Moreover, the team has benefited from growing education opportunities in Kenya. Linda Kwamboka and Susaneve Oguya graduated from Nairobi's Strathmore University with a Bachelor of Science in Business Information Technology. In addition, Susaneve Oguya has been trained by eMobilis where she completed the *MIT/Nokia Mobile Phone Programming for Entrepreneurs* course. The team has also gathered professional experience in the local industry, for instance as Mobile Application Developer in the Safaricom Academy (Susaneve Oguya).

In addition, *M-Farm* was aided by the growing interest among social investors to invest in local ICT start-ups as well as Kenya's growing talent pool of motivated young people (see Section 3.2).

4.6 Opportunities and Challenges for Scaling up

Price information service

The price information service has the potential for significant expansion to reach a larger number of farmers across the country. While the service is unlikely to constitute a significant revenue source for *M-Farm* in the long run due to the low cost of the SMS, the service can be used as an outreach tool to engage farmers who may then sell their produce through *M-Farm*.[103] In addition, the service could also be offered outside Kenya since it is easily replicable in other countries. *M-Farm* has already received requests to offer the service abroad. While the company has decided to firmly establish the service in Kenya first before expanding, they plan to offer the software in other countries while local partners would provide the content.[104]

The main challenge for scaling up the price information service is going to be marketing.[105] In the early stages, *M-Farm* had to undertake extensive personal marketing through local leaders and partners. This process is costly both in terms of money and time. Reaching a wide audience would require a snowball effect where users become convinced of the benefits of the service and spread the word to others. It is unclear to what extent this has happened so far. Anecdotal evidence from the focus group discussions suggests that farmers who did not participate in the group were unlikely to use the service (e.g. in Rachuonyo some of the farmers were not using the service even though they lived in close proximity to the collection centre and participating famers).

In addition, initial knowledge of the service is not necessarily sufficient. In Rachuonyo, for example, some farmers said that they were not using the service because they had missed the training. The analysis of SMS also shows that many farmers did not know how to use the service or which markets or crops they could request prices for. These findings were confirmed in the survey. Thus, repeated training and marketing will be

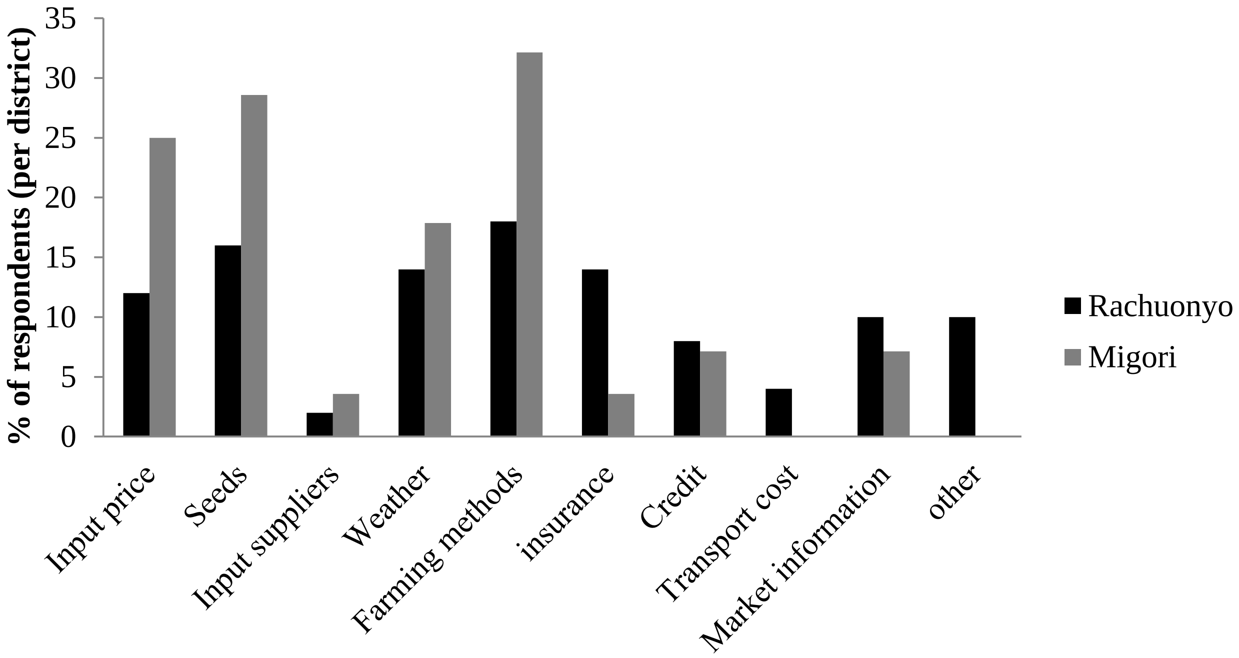
[103] *M-Farm* team, pers. comm. August 2013.
[104] *M-Farm* team, pers. comm. May 2012.
[105] Key informant interviews, May 2012; Jamila Abass cited in Kimo (2011).

required even for existing *M-Farm* users. *M-Farm* can draw on its effective network of aggregators in this regard.

Alternatively to training a large group of farmers in the use of the service, *M-Farm* could also target key individuals in the community. The survey shows that farmers commonly share price information with other farmers within and outside the group. Thus, marketing efforts could focus on those farmers who hold a position of authority in the community. Particular attention could be paid to engaging farmers' cooperatives or groups, given that farmers who are part of a group have been shown to benefit more from market information (Ferris et al., 2008).

M-Farm could also diversify the types of information provided. In the survey and focus group discussions, many farmers expressed interest in receiving price information from other markets, in particular those located nearby. Moreover, about two thirds of farmers would like to receive additional information from *M-Farm* (71% in Rachuonyo and 62% in Migori) (Figure 4-17). The IT infrastructure established for the price information service could easily be used for the dissemination of other information that lends itself to distribution via SMS, such as the price of inputs, information about seed varieties and weather information.

Figure 4-17: Demand for additional information



Note: The graph shows the share of respondents who ask for additional information.
Number of observations: 78
Source: Compiled from survey data collected by the author

Selling

As elaborated above, *M-Farm* offers marketing services through contract farming and its mobile phone- and web-enabled market place. The contract farming arrangements will be challenging to scale up. The arrangements need constant support from the *M-Farm* team who receives numerous phone calls from farmers and buyers involved in the programmes. Managing these interactions would require significant staff expansion if the contracts were to be expanded. *M-Farm* could consider changing its role within these arrangements, for instance to only facilitate the initial contract. However, given the importance of *M-Farm* as a trusted mediator for the farmers, the company will likely need to be involved for some time. Also, the contracts only provide farmers with limited access to new buyers through individual contracts. As the survey results from Migori show, this set-up may not encourage farmers to make the most use of price information. Rather, they appear to focus their efforts on servicing their contractual obligations.

Since early 2013, *M-Farm* has shifted the focus to establishing networks of sellers and buyers in the open market. Such a service could be of great interest to farmers. The survey shows that respondents highly valued information about demand for produce which played a more important role in decision-making during the production process than price information. So far, *M-Farm*'s virtual market is mainly used by near-city farmers, but efforts are being made to expand the reach of the service. Building trust between buyers and sellers will be one of the key challenges of scaling up such a network, given that trading partners often prefer establishing contact and trust through face-to-face interaction first (Molony, 2006; Overå, 2006). Experience with the m-market place *Cellbazaar* in Bangladesh also shows that engaging farmers is likely to take some form of human mediation (Quadir and Mohaiemen, 2009). Thus, the role of *M-Farm* and its partners as mediators will be crucial in the future. To address this issue, *M-Farm* has set up a verification point in Nairobi and is working with the aggregators who verify the quality of crops in the provinces.

In addition, *M-Farm* could consider marketing its SMS-system as a supply chain management system which could be licensed to buyers and farmers groups to manage orders and deliveries. While some m-services already exist to manage sourcing from small scale farmers (e.g. Virtual City's *Agrimanagr* in Kenya or SAP's *Rural Sourcing Management* software in Ghana), these systems are mainly targeted at larger buyers. Thus, *M-Farm* could target smaller buyers or groups who may find other systems too costly or complex to use.

Reaching the poorest

As a standalone service, *M-Farm* is unlikely to be marketed to the poorest farmers because it requires a certain level of market orientation and market access for farmers to be able to make effective use of the price information. Indeed, the comparison of *M-Farm* users with district averages shows that on the whole surveyed farmers and households tend to be better off, better educated, located closer to markets and have better access to phones and radio. Also, poorer farmers usually sell at markets that are closer located and may therefore find price information from only a few large markets less useful. M-Farm is also likely to target farmers that are organised in order to enable marketing of the price information service to a group and to facilitate the collective selling of produce.

To extend the reach and utility of *M-Farm* to the poorest, the service would need to be integrated into a broader, long-term strategy to increase productivity, commercialisation and market linkages. The ADS project is already moving in this direction, albeit on a small scale. Such initiatives would need to be supported by larger scale interventions, such as infrastructure developments (e.g. roads, storage facilities), extension services and the provision of inputs and other technologies. Governments can play an important role in this regard by providing policy guidance, coordination and funding.

5 Summary and Conclusions

Most people in the developing world now have access to a mobile phone, even if they do not own one. M-service providers are increasingly recognising the potential of this market. In the agriculture sector, information services, m-payments and to a lesser extent virtual markets and supply chain management systems are most common. In general, m-services are becoming more comprehensive, offering more diverse and multiple functions that support farmers at different stages of agricultural production – a trend that will need to continue to increase the effectiveness of m-services in agriculture. This section summarises the key findings of the research regarding the theoretical and proven contribution of m-services to agricultural technology innovation processes, the potential of mobile technology trends to broaden the range of m-service that can be offered to farmers, and the utility of a specific m-service (*M-Farm*) in this regard. The section also highlights the contribution of the research to the existing literature and identifies areas for further research.

5.1 Key findings

5.1.1 Engaging farmers in agricultural technology innovation

The dissertation presents a conceptual framework on the role of m-services in enhancing farmers' capabilities to engage in agricultural technology innovation, including the development and adoption of agricultural technologies, by facilitating access to information and learning, financial services and input and output markets. To date, most of the research on the conceptual linkages has focused on mobile phones as such and only a few studies have looked specifically at m-services:

Several studies conclude that the general use of mobile phones to access information has helped to reduce search times and costs. However, other studies also find that farmers rarely use their mobiles for information gathering, preferring face-to-face contacts instead. Regarding dedicated information m-services, four studies point to certain benefits, such as higher income, improved productivity and fewer weather-related crop losses. One study finds that m-services had facilitated learning.

Very little research has been carried out to assess the role of financial m-services to support innovation among farmers. One study finds that famers are using m-payments to purchase agricultural inputs, but these payments constitutes only a small share of transactions.

Research on the role of mobile phones or m-services in facilitating access to inputs is inconclusive. One study reports anecdotal evidence that mobile phones in general have lowered input costs. There is also some evidence that mobiles have helped with job searches, but one study of a related m-service concludes that the service had had limited success because people did not trust the job offers they received through their phones.

Finally, with regard, to output markets, several studies find that the use of mobile phones to access prices and conduct market transactions has reduced price dispersion for perishable produce. However, most studies conclude that mobile phones have had limited impacts on sales patterns as farmers largely continue to sell to their established contacts. To what extent m-services offering price information have benefited farmers is unclear. Two

studies show income gains while three studies do not (see also below). Mobile phone-enabled markets have not been empirically assessed.
To the author's knowledge, no study has looked into the utility of mobile phone-enabled social networks, surveys, loans, savings, insurance, input and output markets or supply chain management for farmers.

Overall, the available studies do not offer sufficient evidence to draw strong conclusions about the suitability of m-service to engage farmers in innovation processes. The evidence is further weakened when critically looking at the methodologies used in the studies. Much of the research relies on farmers' perceptions rather than time series data, which this dissertation and other studies have shown to provide only weak evidence when assessing actual impacts (see also below). Methodological shortcomings are not only found in the study of agricultural m-services. A review of assessments of m-health applications in low and middle income countries also points to a lack of rigor in the design and methodology of most studies (mHealth Alliance, 2012).

5.1.2 Technology trends

Most of the agriculture-related m-services currently available use 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. Key trends include: the growing diversity of mobile connected devices to access m-services; the Internet of Things which links objects and people through the network; and collection and sharing of data and knowledge through the expanding mobile networks and user base.

The dissertation presents two scenarios for the evolution of mobile technology trends. The *Status Quo* Scenario is characterised by widespread use of basic and feature phones and a small number of largely disconnected IoT applications, data collection projects and social networks. Farmers find the services easy to use and affordable, but service functions are limited due to low-tech phones, slow networks and service providers' preference for higher income markets. Under the *Big Leap* Scenario, higher-tech devices are widely used, personal and other mobile devices are linked up through the network, and connected users share experiences through extensive social networks. The more sophisticated devices allow for the provision of more complex information and interactive services, but are more difficult to use and afford for less educated and resourced farmers. IoT technologies, such as tracking devices, weather stations and cameras, are used in insurance schemes, supply chain management and virtual marketing networks.

In addition to analysing global trends, the dissertation also assesses the status of m-services in Kenya. A vibrant technology scene has emerged in the East African country in recent years. The growth of the ICT ecosystem was facilitated by a number of factors. The network infrastructure has improved, both within the country and by linking Kenya to other countries through sea cables. In addition, a supportive innovation environment offers access to innovation hubs, finance and human resources. The growing customer base provides a promising market for m-service developers. Through *M-Pesa*, many Kenyans are already familiar with the use of their mobile phone for non-call related activities. At the same time, the ecosystem is still evolving and much room for improvement remains.

A number of m-services are being offered to Kenyan farmers. In addition to transmission and banking services available to all users, most of the agriculture-related m-services provide access to farming and price information, mirroring the global trend. A small number of mobile phone-enabled insurance schemes and supply chain management tools are also available. While the choice of m-services is comparatively large, their reach and scale remains limited. Also, no data is available to assess the effectiveness of these services. Health-related m-services in Kenya face similar problems. As Patricia Mechael, Executive Director of the mHealth Alliance, notes, only a few health-related m-services manage to survive beyond the pilot phase due to lack of sustainable business models and funding (cited in Talbot, 2012).

5.1.3 Case study: *M-Farm*

The case study examined the impact of the price information and marketing m-service *M-Farm* on Kenyan farmers' decision to adopt agricultural technologies and generate income from their use. The theoretical literature suggests that information about prices and demand can help farmers to decide whether to adopt new technologies by allowing them to evaluate the likely profitability. Improved access to market information and linkages to buyers can also raise farmers' income by enabling them to obtain higher prices for the crops (e.g. through bargaining or access to buyers with better offers) or to increase their returns through changes in production.

Only a few studies have assessed the role of m-services in this regard. Most of the studies conclude based on survey data that m-services offering price information have helped farmers to plan their production better and obtain higher prices. However, in the few studies where data on actual impacts was collected, the positive feedback was not confirmed in practice. Studies have also shown that marketing m-services have had little impact on trading patterns. Looking at the reported reasons for the limited impacts, existing research suggests that unless other factors are addressed, such as broadening opportunities to bargain, to access different traders or to obtain finance from different sources, marketing m-services will not lead to technology adoption or income gains.

Similar to previous findings, *M-Farm* users felt that the price information had helped them in their production planning and thereby adapt their cropping patterns by expanding lucrative crops. The study also assessed the role of price information and *M-Farm* at different stages of production and vis-à-vis other factors influencing decision-making. The research confirms that price information was used for decision-making at all stages of production and most extensively at the sales stage. It also finds, however, that demand information was seen as more important for decision-making at all stages of production.

While many farmers reported that *M-Farm* had helped them obtain higher prices and raise their income, the evidence from the case study is inconclusive. The survey results and analysis of price data indicate that farmers' perceptions are unlikely to be a reliable indication of price increases. Perceived income gains may also have arisen from changes in production patterns, for instance by increasing the production of commercial crops in response to price signals, but the evidence for this conclusion is weak. In line with previous research, the study concludes that price information from *M-Farm* has not encouraged farmers to change traders on a large scale. As the first study to examine the link between price information and marketing services, the research indicates that combining contract farming with price information may in fact be counterproductive because the contract farming arrangement provides a disincentive for farmers to make use of the price information.

The case study adds to the existing literature in a number of other ways. As an additional measure of the m-service's utility for farmers, the study asked about users' willingness to pay for the service. While most thought that the cost of KSh 10 per SMS charged at the time of the study was too high, they were nevertheless prepared to pay a higher price than the usual cost of an SMS. This finding indicates that they perceive the benefits of the service to be sufficiently high to justify additional costs.

Moreover, rather than looking at the impact of the m-service in isolation, the case study sought to place it in the broader context. To this end, the study assessed the relative importance of price information and market linkages as barriers to agricultural technology adoption. The findings suggest that these factors play a role, but are less important than other constraints, such as the risk of crop losses, lack of insurance and limited finances. The study also assessed the actual demand for agricultural technologies which was found to be surprisingly low given limited technology adoption rates among the respondents.

In addition to the impact assessment which is commonly found in empirical studies of m-services, the study also assessed the types of farmers that use the service. *M-Farm* users were found to be better-off, better educated and more commercially oriented than average citizens in the districts. Thus, the service is not reaching the least-resourced farmers in the districts. However, this is likely due the nature of the service which makes it more suitable for market-oriented farmers with different options for selling their produce. Farmers who are mainly engaged in subsistence agriculture are less likely to be able to take advantage of price information and seasonal price trends due to lack of access to alternative markets or storage facilities. Also, in the study sites *M-Farm* was marketed specifically to farmers who are part of the ADS project to improve the agribusiness skills of already organised farmers while the poorest farmers were not part of the target audience.

The study also examined the relative role of mobile phones in delivering the price information service vis-à-vis other information channels. The radio was found to be an equally good source of price information in the early stages of production, but *M-Farm* gained in importance towards the sales stage when farmers required timely information. Thus, disseminating price information both through the radio and the mobile phone (as already being done by *M-Farm*) appears to be the best strategy to reach a large number of farmers.

While the study did not distinguish between male and female farmers in the data analysis, it is interesting to note that female farmers felt empowered as a result of using *M-Farm*. The training had familiarised them with the use of a mobile phone and several of them had subsequently obtained a phone which they could then also use for other business transactions. Further research could examine whether these changes have impacted women's decision-making related to agricultural technology adoption.

The case study also sought to understand the success factors that have contributed to the growth of the start-up company and the expanding reach of its services. Several of *M-Farm*'s business strategies are among the most important factors, including their adaptability to changing circumstances and feedback, the trust they had managed to establish with their customers and the structures set up by their partner organisations. The characteristics of the target audience have also facilitated uptake of the service. In addition, Kenya offers an environment conducive for local start-ups to emerge and grow due to factors such as steadily improving infrastructure, the availability of innovation spaces, access to investors and a growing and comparatively tech-savvy customer base.

Finally, the study assessed opportunities and challenges for scaling up the m-service. While the price information service would be the easiest to scale (including by expanding the types of information provided), it is unlikely to generate the necessary revenue for future expansion due to the low cost of the SMS. High maintenance requirements and unreliable export markets already hinder expansion of the contract farming arrangements. Thus, emphasis will be placed on scaling up the mobile phone-enabled open market. The main challenge here will be to set up and maintain marketing structures (e.g. exchanging information about availability of and demand for produce, transportation, points of sale, quality assurance, financial transactions etc.) that are trusted by both buyers and sellers.

A number of methodological constraints in the case study should also be mentioned. The survey approach to assessing the use and impact of an m-service has several limitations. While the respondents tried their best to answer all the questions, it is clear from the answers that they sometimes found it difficult to do so, for instance with regard to questions about income, sales volumes, crop prices, distances or travel times. Thus, these data need to be read with some caution. Respondents struggled in particular to talk about events in the past (such as questions about information sources before and after using *M-Farm* which many found confusing) which makes it difficult to assess changes over time with only one round of surveys. Difficulties also emerged when establishing causalities, for instance to differentiate between impacts due to *M-Farm* and ADS activities or between impacts due to price information and market linkages. Responses also differed when interviewees were asked open or multiple choice questions. In future research, baseline studies prior to launching the service, including both surveys and other numerical measurements, would be needed to better understand changes over time and rule out confounding effects.

5.2 Further Research

As noted above, further empirical research would be needed to substantiate the specific conceptual linkages presented in this dissertation. In addition, a number of overarching research gaps can be identified.

Existing research on agriculture-related m-services has to date rather narrowly focused on assessing impacts of a given service on specific indicators, such as income or productivity. A more business-oriented perspective would be needed if m-services are to move beyond the start-up phase. Such research should focus on why the service has succeeded (or not), how it could be scaled up, whether (and when) it is likely to be sustainable in the long term and whether the benefits achieved justify the investment in the service. More *ex ante* studies would also be required to inform the design of m-services rather than focusing only on impacts once the service has been launched.

Most of the research could benefit from a more user-centred approach which assesses the actual needs to be addressed, the most suitable design to enable easy and effective use by different target groups, and the advantages of delivering the service through mobile phones versus other channels. A greater differentiation between users by income and social groups as well as gender would be helpful in this regard to better understand the needs and capabilities of different types of farmers and design m-services accordingly. In addition to tangible benefits, studies should also investigate the role of mobile phones and m-services in empowering farmers and overcoming barriers of distance and social standing.

In particular the suitability of m-services to address the needs of the poorest and marginalised farmers remains seriously under-researched. Judging from the little evidence gathered to date, the small and less-resourced farmers benefit less from m-services as a result of lower income and education levels. However, it remains to be explored whether m-services are generally less relevant for the poorest farmers or whether existing services have simply not been designed in a way that suits their needs. Moreover, as phone sharing remains a reality in particular among the poorer users, the associated dynamics need to be better understood, including within households, communities and organised groups such as cooperatives.

It is also important to bear in mind that any impact assessment of an m-service is only ever a snapshot of the present. In addition, such assessments should also look ahead to understand how new technology trends could help to tackle the problem that the m-service is trying to address. Having said that, many of the new technological opportunities have not yet been realised in practice – neither in industrialised nor 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.

In terms of methods applied in the studies, many researchers rely on farmers' perceptions obtained through surveys, but rarely collect other quantitative data. The case study highlights the shortcomings of the survey approach in assessing impacts of m-services. Instead, longer term studies are needed that record data over time, such as changes in production costs, yield, prices, income or other human development indicators. It is also critical to bear in mind possible confounding effects, given that farmers who are using m-services may also be the type of innovative farmers who are more likely to adopt new agricultural practice or sales strategies that increase their productivity and income. Carefully designed experimental studies could help to rule out possible selection biases and spurious correlation.

Finally, the broader impact of m-services development and adoption on the economic development of a country warrants further analysis. Such research could look at the economic impact of actual m-services in different sectors, but also spillover effects on other parts of the economy, resulting, for instance, from the associated growth in local innovation capacities or from infrastructure improvements stimulated by m-services adoption.

In conclusion, the research has shown that the use of m-services for development purposes is garnering a lot of enthusiasm among national governments, investors, international organisations, the media and consumers. Indeed, looking at the specific case of using m-services to engage farmers in innovation systems highlights the potential of existing and future technologies in this regard. However, to date most m-services have not yet reached scale or generated significant returns, and the positive impacts have rarely been empirically proven. Nevertheless, it is possible to build on this enthusiasm, in particular among consumers who are obviously willing to engage with the new technologies, to increase the value of m-services in development, based on more user-centred research to inform the design of m-services and assess their impacts.

At the same time, m-services will only ever be part of a broader solution, given the complexity of the challenges that farmers in the developing world commonly face. Thus, m-services should be embedded in complementary support programs and infrastructure developments to tackle other production and marketing limitations. Advances in mobile technologies could provide further opportunities to extend the functionalities and impact of m-services, provided that they do not result in solutions that go beyond the financial and human resources capacities of smallholder farmers.

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Annex: List of Questions and Interviewees

Guiding questions

1. What are the main challenges for smallholder farmers in Kenya to access, use and generate income from new agricultural technologies (e.g. seeds, inputs or farming practices)?
2. What is the role of m-services in addressing these challenges?
3. Do you see a business case for offering m-services in agriculture?
4. What are the limitations and challenges of m-services?
5. What is the advantage of using mobiles to deliver services over other channels? Could services also be delivered through or in combination with other channels?
6. What are the experiences with existing agricultural m-services in terms of:
    - Needs addressed (and how they were identified)?
    - Services delivered?
    - Use of the services?
        - Number and types of users (inclusiveness)
        - Mode of use
        - Usage
    - Impact on agricultural technology adoption?
    - Success factors?
    - Challenges?
    - Additional support needed?
7. Are there any lessons that can be learned from providing m-services in other sectors?
8. What complementary activities would be needed to make m-services more effective and facilitate agricultural technology adoption?

Interviewees

Angela Crandall, Research Project Manager, iHub Research, 26 April and 18 May 2012

Nicholas Daniels, OneAcre Fund, 12 May 2012

Evans, East African Growers, 17 May 2012

Carsten Friedland, SAP, 5 and 12 April 2012

Rose Goslinga, Syngenta Foundation, 16 May 2012

Annemarie Groot Kormelinck, Wageningen UR, Centre for Development Innovation, 29 May 2012

Stephanie Hanson, Director of Policy and Outreach, One Acre Fund, 20 March 2012

Erik Hersmann, Co-founder of the iHub, 7 June 2012

John and Rachel, Pea farmers in Kinangop selling to EAG through *M-Farm*, 17 May 2012

John Kieti, Manager, m:lab, 15 May 2012

Joy Kiiru, Lecturer, School of Economics, University of Nairobi, 3 May 2012

Willis Kosura, Professor, Department of Agricultural Economics, Faculty of Agriculture, University of Nairobi, 30 April 2012

Sharon Langevin, Project Manager, FrontlineSMS:Credit, 14 May 2012

Silas Macharia, Chief Commercial Officer, Virtual City, 15 May 2012

Ken Mwanda, Managing Director, eMobilis Mobile Technology Academy, 8 May 2012

Tobias Moga, Secretary of the Sweet Potato Cooperative, 25 May 2012

Lynette Njogu, Marketing Manager – Orange Money, Orange Telekom, 27 April 2012

Samson Ochieng, Chairman of the Passionfruit Group in Migori, 30 May 2012

Victor Oduor, Head of Programs, Radio Nam Lolwe, 23 May 2012

Susaneve Oguya, *M-Farm* Ltd, CTO and Co-founder, 1 May and 7 June 2012, 2 August 2013

Julius J. Okello, Senior Lecturer & Agribusiness Management Program Coordinator, Department of Agricultural Economics, College of Agriculture and Veterinary Sciences, 24 April 2012

Vincent Orwa Alila, ADS, 21, 24 and 29 May 2012

Paul Osiro, Unit Manager, Kenya Women Finance Trust Limited (KWFT) Migori, 29 May 2012

Natalia Pshenichnaya, mAgri Business Development Manager, GSMA, 3 May 2012

Nat Robinson, CEO, Juhudi Kilimo, 11 May 2012

Eric Schütz, Fraunhofer FOCUS, 30 July 2013

Estelle Verdier, Product Manager, Marketing Department, Orange Telekom, 27 April 2012

Brenda Wandera, Project Development Manager, Index Based Livestock Insurance, 2 May 2012

Rachel Zedeck, Managing Director, Backpack Farm, 10 May 2012

Mobile phones have reached some of the most remote parts of the globe. Their rapid spread offers opportunities to improve the lives of small-scale farmers across the developing world. Indeed, companies have already started to capitalize on this trend by using mobile phones to help farmers to access information, banking services or virtual markets. This dissertation examines how mobile phone-enabled services (or m-services) could facilitate the participation of farmers in agricultural innovation processes. The focus is on Kenya which has emerged as a frontrunner in the development of m-services in Sub-Saharan Africa. The dissertation outlines the key factors that have helped the local innovation scene to emerge and reviews existing agricultural m-services available in the country. The in-depth case study of the Kenyan company M-Farm, which offers price information and marketing services via SMS and the Internet, critically examines whether the m-service can live up to the expectations. The dissertation also reviews current mobile technology trends to provide an outlook on potential future applications in the agriculture sector and beyond.