The Potential and Limitations of Mobile-learning and other services in the Agriculture Sector of Kenya Using Phone Applications

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Abstract
Low productivity, income and food security in Kenya are often due to low level of adoption of modern agricultural technologies. Smallholder farmers, who produce the majority of agricultural products, face various challenges, including access to adequate information, services, and key value chains. Effective dissemination and adaptation of generated knowledge, practices, and technologies to diversify production and foster resilience to recover from shocks and stresses amongst farmers are lacking. Regular extension services have failed to achieve the transformation from subsistence-oriented production to productive (semi-) intensive farming practices encompassing modern agricultural technologies. Information and Communication Technology in Africa is developing fast and the use of mobile phones has progressively moved beyond mere communications. Technology start-ups are taking advantage of the conducive environment in Kenya and build mobile applications that offer health, banking and, increasingly, agricultural services. Agriculture applications can provide farmers with an array of services from production systems management to climate information, and market access. Yet, while many of these applications have real potential to further social and technological transformation, particularly by engaging the youth and providing data to the government, they struggle with distribution and the set-up of sustainable business models.

Keywords: Africa, mobile training, information dissemination, resilience

Introduction
Similar to many other African countries, the agriculture sector in Kenya is regarded as one of the main drivers of the country's economic growth. It employs about 70 per cent of the population, both directly and indirectly, and contributes about 25 per cent to the Kenyan Gross Domestic Product (KNBS, 2014). The sector is composed of mostly rural smallholder farmers that practice rain-fed agriculture on less than 3 ha of land, which produces about three-quarters of the country's agricultural output (GoK, 2010).

On-farm productivity however remains low, trapping farmers, who have very few alternative sources of employment and income, in a poverty cycle. Low agricultural productivity is often linked to low adoption of improved agricultural technologies, including better cultivars, fertilizers, pesticides, and practices (Aker, 2010). A mix of several factors prevents the adoption of new agricultural technology and innovation by farmers and involves the level of education, individual risk preferences, capital, perception, as well as inputs such as land, labour and credit, as well as access to information (Aker, 2010). Relevant and suitable information on best practices, new technologies, post-harvest handling, and value-addition are key in order to boost productivity (Munyua et al. 2009). Other factors include complex structural challenges, such as access to quality inputs, markets, technology, and loans (Salami et al. 2010). Unable to diversify or adopt better technologies and practices leaves small holders vulnerable to the impacts of natural hazards, such as extreme weather events or pest and disease outbreaks. Hence, when disasters cause crop, livestock and income losses, poorer farmers are the least able to recover, further aggravating food-insecurity and poverty.

New mobile phone-based agriculture services are increasingly offering solutions to address challenges as traditionally extension services are struggling to fill the knowledge gap and drive structural changes. This paper provides an outline of which mobile agricultural applications exist in Kenya, how they developed and what impacts Information and Communication Technologies (ICTs) could have on agricultural training and service provision. It will further examine how their various

features can increase the adoption of agricultural technologies, access to key services, and integration into profitable value chains, and as a consequence enhance resilience and foster social and technological transformation of farming systems. The research for this work involved a desktop review of secondary sources of information as well as interviews with the key app provider in Kenya.

Resilience and promotion of sustainable farming systems

Over the last decade, resilience has become a key concept in international development. The concept also underpins the newly adopted Sustainable Development Goals, which build the basis for a new development agenda (UNISDR, 2015). While precise definitions vary between organisations, the United Nations' Food and Agriculture Organisation (FAO) defines resilience as: *"the ability to prevent disasters and crises as well as to anticipate, absorb, accommodate or recover from them in a timely, efficient and sustainable manner. This includes protecting, restoring and improving livelihoods systems in the face of threats that impact agriculture, nutrition, food security and food safety."*

Advances in building resilience into agriculture are largely clustered around the following four key components: soil fertility; water-availability; diversification; and a strong local community (Thompson et al., 2015). Considerable research and development has been conducted to intensify crop and livestock production, improve agricultural technologies and develop resilient food production systems (Juma et al., 2013). Such practical farming systems include conservation agriculture (CA), agro-ecological farming and climate smart agriculture (CSA), amongst others. They share various common principles and practices, such as integrated pest management, crop rotation, and sustainable water management practices, like rainwater harvesting or irrigation efficiency.

One of the main challenges to achieve high productivity and resilience is the effective dissemination and adaptation of the knowledge, practices, and technologies. Farmers need to be able to access this knowledge and practices to profit from these advances and to be accurately trained to foster their long-term adoption. Various public-sector programs and international development agencies initiatives focus on distributing new practices to often remotely located farmers. Yet, reaching smallholder farmers, particularly in remote regions, is time-consuming, expensive and has shown limited results in terms of adoption of improved agricultural technologies.

Traditional extension services, such as the trainings and visits (T&V) system, extensively promoted by the World Bank during the 1970s, do provide a high rate of return of investments (Birkhaeuser et al.,1991). Good extension services require adequate and well-trained extension staff and continued funding for training and follow-up visits (Birkhaeuser et al.,1991; World Bank, 2005). Verification of their impact on adoption of agricultural technologies and productivity remains limited despite decades of investment in and experience with a variety of public extension programs. Reducing the effects of extension services, are their limited geographic scale and poor sustainability, as well as low motivation and accountability of the field staff (Anderson and Feder, 2007). The quality of the Kenyan extension service varied strongly during the different political eras and between the geographic regions. The currently undergoing political devolution process, which was initiated in 2013 and involves the transfer of health, education, transport and agriculture services to the 47 counties, it has let to very mixed extension provision between the newly formed counties.

Other extension channels for agriculture information are TV, radio and print media and manuals that might create initial interest in new systems with farmers, but are static tools and do not allow questions, clarification or in-depth training. These tools and extension services primarily address the information gap, yet do little to address the structural challenges farmers face, and hence lack the transformative power required.

The latest information and training tool, which many famers already carry in their pockets, is the mobile phone. In theory, once set up with the relevant applications, both smart and none-smart phones, have the potential to inform, train and monitor farmers, as well as change operational processes when established as open platforms that include input supplier and markets.

Mobile subscription and use

Following global trends, mobile phone ownership and sim-card subscription are continuously growing in Africa. Sub-Saharan Africa (SSA) recorded 389 million unique subscribers in 2015 representing a penetration rate of 41% as reported by GSMA (2015), the representing body for all mobile operators globally. Yet, mobile phone subscriptions vary greatly between countries, with a mobile penetration in Kenya of over 80% and only 34% in neighbouring Ethiopia. One factor why the numbers of mobile phones users are still trailing behind the rest of the world is affordability. With 43% of Africans still living on less than $1.90 a day (33% in Kenya), many cannot afford the cost of a handset or regular phone credit (Beegle et al., 2016). Still, many people have access to a mobile phone through 'device sharing' between family or community members without owning a phone. Illiteracy and digital illiteracy are additional barriers that limit use of mobile phones or their functions.

An inconsistent and slow network is the key technical barrier in many regions in SSA. However, GSMA (2015) projects that by 2020, a more extensive network coverage will be available, offering high-speed mobile broadband connections i.e. 3G and 4G technologies. Based on this the developing world will experience an increase from currently less than one-third to nearly reach two-thirds of all connections running on mobile broadband networks in 2020 (GSMA, 2015).

ICTs, in particular mobile phones, are not only used to communicate, but also to access information and a growing range of new applications and services. In Kenya, these increasingly include to make or receive payments, access political news or look or apply for jobs (PEW, 2015). Mobile phones applications ("apps") are software applications designed to run on mobile devices. They are having an increased impact in terms of making crucial information available in the fields of health (mHealth) or services, such as banking (mobile money), where mobile phones have transformed consumers' banking behaviours and promoted financial inclusion in the region (GSMA, 2013). Paving the way in Kenya was the mobile banking application M-Pesa, which was launched by the mobile phone provider Safaricom in 2007. Currently used by over 15 million Kenyans, M-Pesa allows users to send and receive money, pay bills, save, or use cashless payment services. High mobile phones ownership and M-Pesa's prominence and the resulting cultural transformation, have shaped a new realm, with tech innovations continuously expanding the list of new services and applications.

Information and Communication Technology for Agriculture

While the mobile app landscape in SSA is still dominated by health and finance services, agricultural support solutions, often referred to as mAgr or m-agriculture, have entered the field. A wide range of applications provides information and services via voice, short message service (SMS), USSD (Unstructured Supplementary Service Data – a message service allowing access to data through a menu structure), and the Internet (Aker, 2010). ICT's main function and core value is the ability to collect, process, exchange and distribute information (Brugger, 2011). Agriculture apps can roughly be categorised into the following four themes: 1) ICT for production systems management, 2) ICT for market access services, and 3) ICT support services, including financial inclusion and 4) data collection (Brugger, 2011, FAO, 2013). Many apps-providers frequently bundle some of these functions, aiming to offer one- stop shops solutions for their customers.

Various agriculture-based mobile phone apps such as iCow, mFarm, Esoko, M-Shamba, FarmDrive, Plantwise, Haller Farm app, M-Samaki and WeFarm, have been launched in Kenya that target underserved small-scale farmers. It is mainly young developers living in Nairobi that have initiated many of these start-ups. They see the opportunity to tackle challenges that their families and friends face in their rural homes.

Several advantages make mobile applications a great addition to traditional extension tools. In contrast to extension service network, mobile phone apps are instant, interactive, far-reaching and relatively low-cost, with a range of benefits and expandable features. Agricultural apps can offer a suitable solution to help farmers to adopt modern and sustainable farming practices, build clusters and offer vitals links to input provider and local markets in poor and remote areas where farmer are unable to access the Internet or have no or little support through extension services.

Apps potential to increase resilience

At the sector-level, it is clear that in order to holistically strengthen resilience on national-, community- and the individual-level complex governance and policy reforms are required. Factors that drive resilience such as improved infrastructure, research and coordination, must be integrated into public investment policies and planning.

More pertinent to measuring apps capacity to promote resilience is to examine their impact on the farmer-level. One methodology often used to illustrate how resilience can be achieved at the farmer level is the 'sustainable livelihoods approach', adopted by Oxfam Great Britain in the early 1990s. Market-oriented and diverse livelihood-strategies are thereby believed to lead to progressive livelihood outcomes, such as less vulnerability and improved income and food security. Following this market-based approach to improve rural livelihoods, agricultural apps have the potential to offer better access to a) information, b) extension services, c) links to markets and d) finance in Kenya. As illustrated in figure 1, existing agricultural applications promote productivity and performance of individual farmers, as well as whole agricultural value chains and include supporting services and connected sectors. To give a specific example: a farmer can be made aware about the benefits of a technical advance such as a greenhouse, get access to credit to afford this new technology, and receive training on how to best use it, order inputs and find a market to sell the products grown in the greenhouse. Smoothening those traditional bottlenecks empowers farmers to have the opportunity to make informed choices, access technical and financial services and participate in lucrative value chains.

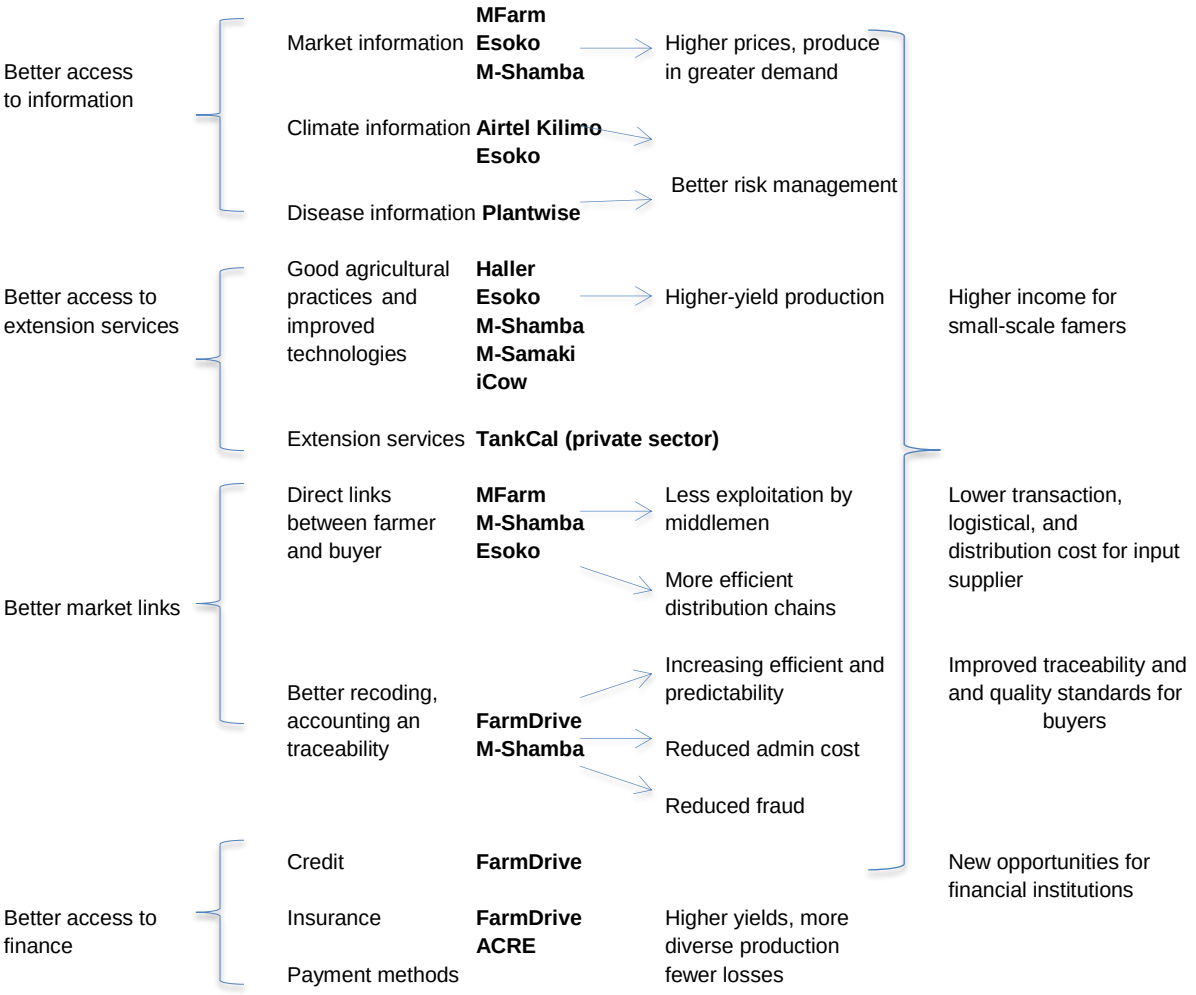

Figure 1: Potential Results generated by Mobile Applications for Agricultural and Rural Development in Kenya
Source: Modified after Qiang et al. (2011)

How these app services foster resilience becomes apparent when breaking down the above cited definition of “resilience” and match it with services that agricultural apps can offer:

" *resilience is the ability to*	- ***prevent*** *disasters and crises*	> good agricultural practices & improved technologies
as well as to the ability to	- ***anticipate***	> climate & disease information
	- ***absorb***	> crop & livestock insurance
	- ***accommodate***	> good agricultural practices & improved technologies
	- ***recover***	> access to credit

…from them in a timely, efficient and sustainable manner.”

Information and training

Agricultural apps can provide relevant and up-to date information on best practices, crops and new tools. In practical terms: for farmers to know what soil conditions, climatic and water requirements new varieties of crops have before planting, allows for information-based decision-making.

Several apps go further than just providing information. They teach new skills or farming practices, through regular sms- or voice-based tutorials. Training farmers ‘on the job’ and on their farms, follows a ‘learning-by-doing’ approach, increasing the likelihood that they will eventually “own” and adopt those improved practices. The crucial advantage of such apps is that they allow the user to inquire, learn and train at a time and place of their convenience. Also, information and services can, if network permits, be accessed promptly and when specific information is needed. Additionally, research in mobile-learning has shown that through regular contact, participants remained more committed and showed significant better results (Ayoma and Oboko, 2013).

Examples of this type of app available in Kenya include **Haller app, which** provides detailed farming instructions to smallholders, varying from how to increase soil fertility to how to maintain a beehive. **M-Shamba**, targets small-scale crop and poultry producers and teaches best practices. **M-Samaki** guides fish farmers through a complete fish production cycle; giving advice on topics ranging from feeds and pond health to marketing and harvest. **iCow** tracks cows’ lifecycle and retains all relevant information specific to each cow. **WeFarm** provides free peer-to-peer sms-based advice. Launched in 2011, it currently has 43,000 users in Kenya, Peru and Uganda that ask and answer questions, covering topics such as livestock and crop diseases and new farming. Providing a much more comprehensive management solution is ***M-Shamba’s Farm System*** function that allows farmer to track farm activities including revenue and expenses. This addresses a large practical challenge for farmers and a key component of provability, which is record keeping.

Various companies also started using apps to inform and teach customers about their products. Syngenta’s **TankCalc** aids farmers to calculation the right measures for their plant protecting products.

Climate information

In a country where agriculture is over 90 per cent rain-fed, receiving climate and weather data helps Kenyan farmers to plan farming activities and to decide when to plant their crops.

Good climate advice can proactively prepare smallholder farmers to become more climate-resilient, in particular when linking forecasts directly to explicit agronomic advice on how to respond to specific weather conditions. The GSMA even goes as far as recommending *„donors to put weather forecasting and monitoring at the core of climate adaptation funds, and to focus on mobile-centred projects in order to increase the opportunity to scale services and generate socioeconomic impact“* (GSMA, 2016, 4).

Yet, in order to be relevant, climate data and advice needs to be site-specific, which currently is often not the case. This has two reasons. Unless farmers have a smart-phone with GPS functions, it is

difficult to determine their exact location, due to the lack of a formal street address system. In addition, Kenya's many localised micro-climates make exact forecasts particularly difficult.

'Climate apps' available in Kenya include **Airtel Kilimo**, which providing forecast for the coming week, based on data provided by the Kenyan Meteorological Department. **Agro-Weather Tool**, funded by the World Bank, aims to increase the adaptive capacity of farming communities in Kenya and Ethiopia trough improved access to information on weather and climate patterns. One of **ESOKO**'s many services includes sending SMS messages with weather and agronomic tips.

Access to credit

Many banks and financial institutions have traditionally shunned agriculture loans, as lending to smallholder farmers is perceived as high cost, high risk and with low-returns. However, tackling the unmet demand for credit by farmers also helps foster resilience, as access to financial services is crucial for smallholders to make long-term investments to enhance productivity, quality and diversity. Affordable, collateral-free credit allows farmers to, depending on their respective priorities, invest in a) sustainable climate-smart technology, such as drip irrigation systems; b) means to increase productivity, by for example diversifying their crop or livestock profile; c) improved post-harvest practices, such as building better storage facilities or d) value addition methods like building a smokehouse for smoking fish. Moreover, access to loans grant farmers the opportunity to commence or expand into different non-farming activities.

Microcredit schemes have a positive impact on farm productivity and generally a good repayment rate (Okon, Etim, & Offiong, 2012; Girabi & Mwakaje, 2013). Yet, as Adams and Bartholomew (2010) point out, microcredits are often not effective if farmers lack business skills and access to markets for their products.

The Kenyan app **FarmDrive** addresses the high-risk challenge by generating individual credit profiles, based on farm information and expenditure and profit history. They currently offer two types of loans: an input financing loan and a diversification loan for larger investments, such as irrigation systems; Farmers borrow on average is around 15,000 - 20,000KES (150-200 US dollars).

Price information and market access

One of the most common ICT interventions, aiming to provide more financial transparency in the agricultural value chain, are pricing services. Farmers receive prices of a range of commodities either on demand or pushed in pre-set intervals. A second type of service allows farmers to use their mobile phones to trade and market their produce, via trading platforms that match producers with buyers.
These services provide farmers with better market intelligence, first in the crop selection at the production stage and later, by providing better bargaining power during the selling process. As trading platforms can link remote farmers to regional markets, they support the emergence of a more diverse rural economy (McNamara, 2009). Improving market-access for smallholders advances their resilience by enabling poor farmers to participate in higher-value agriculture chains, which in turns improves their income (McNamara, 2009). Trading platforms also eliminating the middleman, thereby driving structural changes in the value and supply chain and increase profits for farmers.

The Kenyan 'pricing app' **M-Shamba** offers a marketplace function that has been designed to promote trade of agricultural commodities while using basic mobile phones. Farmers can post their products using SMS, android app and via the internet. **MFarm** offers a „Daily Prices" update with price information on 42 crops in five urban markets, as well as a marketplace service**. Esoko** not only links buyers and sellers, but also create SMS alerts on prices and buyers for selected crops. **ConviFarm/Kilimo Rahisi** app combines various services and connects rural farmers with information and services offered by agricultural related companies based near the user. This simplifies farmers' access to inputs and increases customer base of agro-based companies. Sectors covered include beekeeping, organic farming, irrigation services, rabbit rearing, hydroponics, livestock feed.

Insurance

Insurance is another financial innovation that can build resilience for farmers. Originating in the United States of America to help agricultural producers recover from the effects of the Great Depression and the Dust Bowl, they insure farmers against losses that are unavoidable and beyond the farmer's control. In the African context, insurance can save poor farmers from the complete loss of their livelihood after a disaster and help to restore their farming systems for production in the next seasons.

The Kenyan app **ACRE** formerly known as Kilimo Salama which in Swahili means “Safe Agriculture”, is a micro-insurance program designed for Kenyan farmers, build through the collaboration of Syngenta Foundation for Sustainable Agriculture, UAP Insurance and Safaricom. **FarmDrive** is in the process of incorporating crop insurance, so that the farmers take out loans will be able to bundle these with crop insurance.

Apps and social and technological transformation

Returning to the ‘sustainable livelihoods approach’ framework helps to establish how the numerous services and functions, which agriculture apps provide might assist to transform related processes and structures and foster some of the social and technological transformation required.

That agriculture apps have the potential to instigate social transformation becomes apparent when considering their great ability to reach and engage the youth in Kenya. Defined as the population between 18-35 years of age, the youth represent 37% of the population, but constitute more than 70% of the unemployed (IEA, 2016). Yet at the same time, young people increasingly abandon agriculture as a source of employment and migrate to the cities to look for alternative opportunities. The average age of farmers in Kenya today is 60 years (UNDP, n.d.). Re-engaging the youth through the means of agricultural apps could therefore help tackle youth-unemployment and an aging-farmer population. A key advantage is that by providing relevant advice and proficient services, apps can change young people’s attitudes towards agriculture, by encouraging them to approach farming as a profitable business. Agriculture apps therefore take advantage of the “youth’s affinity for using ICTs, their capacity to innovate and their propensity for taking higher entrepreneurial risks” (IICD, 2013, 4) a report by the IICD found. 90% of the 24-38 year old farmers in Western Kenya that were researched use ICT in their farm, which further confirms this hypothesis. The report also stressed that more young people had shown an interest in investing in farming lately, which the farmer representatives that had observed this trend, linked to the various ICT applications that had recently been introduced.

A process that take place, often by default or as a side-process, is that agriculture apps collect a large amount of information on their users, commodity prices, climate records, which in its sum is referred to as “big data”. Using and analysing this data could help governments to better monitor, analyse and react to developments in the field. This independently-gathered data could be harnessed and providing evidence-based policy making, more targeted extension service provision and more effective resource allocation. This potential has been recognised by the application providers themselves. **MFarm** is specialised on selling their data to companies, NGOs and government bodies, offering various licences to access their database. **Esoko** offers agricultural data collection, using their trained field researcher team.

Another possibility for governments to use mobile applications in agriculture would be through a specifically designed app to monitor, support and verify the work of their extension officers. Or even outsource some parts of extension services, following the example of a project in Uganda. There, the Grameen Foundation recruited and trained rural community members to act as trusted agents in their communities and to use simple Java-enabled mobile phones to provide information services to farmers, including farming practices, market conditions, pest and disease control, weather forecasts, and to collect data from villages (Brugger, 2011).

As mentioned before, agri apps can foster the technological transformation by supporting the uptake of new improvements in technology. While it might seem obvious, the first step for improved agricultural technologies to be taken up requires that farmers have heard about them. According to

Rogers (2003), forerunner of the diffusion of innovation theory, the first stage in the innovation adoption process is, “knowledge”, followed by “persuasion”, “decision”, “implementation” and “confirmation”. While a mix of factors subsequently influences the actual rate of adoption of a new innovation, awareness is a fundamental prerequisite. Those agricultural apps with training functions can furthermore promote the “implementation” of agricultural innovations.

Apps technological transformation potential increases further when combined with sensor technology. Various types of sensors that monitor temperature, soil fertility and water quality facilitate more precision in farming. How this kind of technology can be applied has been demonstrated by **M-Poultry** in Uganda. Farmers monitor the temperature sensors in chicken-brooders and food and water availability via a sound sensor through their phone.

Challenges

However, while agricultural apps do offer a lot in theory, there are considerable challenges in the field.

Paradoxically, most apps struggle with one of the key problems that they are attempting to solve: Distribution. Apps often perform poorly when it comes to their own marketing and distribution, which incorporates the interlinked components of dissemination, comprehension and long-term uptake or adaption. While initially only a small user-group might be required during the trial and test phase, a significant scale-up is often essential to guarantee the financial sustainability of the start-up business in the long-term. **iCow**, a widely acclaimed Kenyan app which has been running for over five years, is unknown to dairy cooperatives within a four hour radius of the company’s-base in Nairobi, a group of USAID researchers discovered (Burns & Dolan, 2014). M-Farm, they found, has fewer than 20,000 users. This relatively low adoption of applications and services is mainly due to low awareness of their existence. Burns and Dolan conclude that in order to spread distribution, apps services need to expand their marketing and outreach.

Tightly linked to the adoption is the actual understanding of the new service and its functions. While some apps, such as weather and pricing services, are straightforward, some more complex solutions like **FarmDrive**, that combine services, still need a formal introduction and training. One solution is to introduce the application in capacity building workshops. However, awareness campaigns and training for user acquisition often become a major cost-factor for tech start-up apps, which are generally short on funding.

Related to distribution is the challenge of ensuring the actual long-term adoption of apps solutions. Much depends on the users seeing the added value in the service-provided and if they are willing to pay for the service. To ensure the applicability and usefulness of these applications requires a thorough user research and design process; generally the first step in the development process (Burns and Dolan, 2014). Key to the further uptake and understanding of the content-communicated is to offer services in well-timed portions, in a language that is understood, both linguistically and comprehensibly (i.e. using farmer language) and distributed in a suitable format. This would, for example, mean choosing a short voice-message service in a region with high illiteracy, in the locally spoken language, using simple and widely-used terms. Additionally, it is wise to monitor the users experience and test if content and features are understood, relevant and can, if possible, be further fine-tuned.

Many agricultural apps give farmer the opportunity to ask questions or to give feedback, unlike other agricultural information channels, such as newspapers or radio. The use of these apps can advance a participatory process, allowing farmers to provide input on the pertinence of the services and advice shared and vital insights to realities on the ground. Perhaps most importantly for agriculture app providers is to design their product in ways that include such crucial feedback loops and promotes user-involvement on content and functions so allowing their services and information to be interactive, suitable and relevant.

Another challenge, shared with other tech start-ups is financially sustainability. Currently, the majority of agriculture apps are partially or completely funded through donors, charities or incubator programs. To achieve commercial sustainability and to turn sms-based information service into a business, without donor funding is still very difficult (Southwood, 2013). Most common funding model rely on charging the user a small fee for each sms sent, which is split between the network operator and the application developer. Yet, so far only very few agricultural apps have managed to generate the user-volume required to finance their business and recoup the cost of operating the service in this way.

The final challenge is the limited interaction and functions of basic phones i.e. non-smart phones, which the majority of mobile phone users own. Mobile phone applications real potential is best-realised through smart-phone driven applications, such as instant messaging and video streaming. As

most people are visual learners, new information and training have a higher impact when supported by short videos and pictures. Influenced by the technical capabilities many of the agriculture app services in Kenya, start with an Android version for smart-phones, but later shift to basic phone versions, after realising that their user-base still own basic phones. Currently smartphone ownership is too low in rural Kenya to make Android apps viable. More affordable smartphones, together with an improved broadband network however, will likely see a rise in adoption of smart phones (Ericsson, 2014).

Conclusion

In this paper it has become apparent that agriculture apps offer a range of services and functions that can, if adopted, allow farmers to be better informed, take up improved technologies and integrate into value chains and thus improve their productivity and resilience. The use of mobile applications could also help to re-engage the youth into farming and improve and speed up extension services. They can furthermore assist in advancing some of the social or technological transformation needed, though since these are multi-faceted, gradual processes, they will require time and sustenance through other initiatives.

Agriculture apps, however, are not the 'silver bullet' that is able to solve all challenges for smallholders; they are an additional tool in the toolbox. Still essential for them to work is to strengthen the agricultural sector as a whole, through agricultural research, supportive policies and programs, to improve market access, rural infrastructure and the better collaboration between stakeholders (local and national institutions, the private sector and NGOs). Apps can only deliver information that is tested and verified; they can only provide good climate data, if it has been recorded and made available and only build linkages along value chains if those do exist and to markets that are accessible.

It is currently too early to judge what impact ICT-based agricultural services can really have, since their diffusion and long-term sustainability are still big obstacles. So far, very little research has been conducted on actual impacts of applications as empirical trials are complicated due to a range of threads including serial correlation and spill over effects, as highlighted by Aker (2010). Future research should focus on how mobile phone apps can be made more accessible and increase the uptake, and how participatory processes can be further improved in terms of feedback and uprating on content and services vital to farmers.

The potential of the ICT sector is of great interest to the development sector. USAID runs various ICT programs, the FAO has developed the SAFA Smallholder App for soil analysis and GIZ recently launched the ICT4Ag Coordination Unit, looking to accelerating the adoption of tech solutions for their numerous projects and within agriculture value chains.

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