Why Don't Farmers Use Cell Phones to Access Market Prices? Technology Affordances and Barriers to Market Information Services Adoption in Rural Kenya

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Why don't farmers use cell phones to access market prices? Technology affordances and barriers to market information services adoption in rural Kenya

Susan Wyche and Charles Steinfield
Department of Media and Information
Michigan State University

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Abstract
Providing smallholder farmers with agricultural information could improve economic development, by helping them grow more crops which they could then sell for more money. Widespread mobile phone ownership in Africa means that, for the first time, there is a realistic opportunity to deliver pertinent information to remote farmers throughout the continent. Efforts to harness the potential of mobile phones include the development of agricultural market information services (MIS)—applications that send farmers crop pricing information via short message service or SMS. These services promote economic development among some farmers in the developing world, but not yet in rural Kenya. To understand what factors impede the adoption of these services, we qualitatively studied Kenyan farmers' mobile phone usage patterns and their interactions with *MFarm*, a commercially available MIS. Using affordance theory to guide our analysis, we discovered a mismatch between the design of MIS and smallholder farmers' perceptions of their mobile phones' communication capabilities. We use these findings to motivate a design agenda that encourages software developers and development practitioners to adopt an ecological perspective when creating mobile applications for sub-Saharan Africa's rural farmers. Strategies for implementing this approach include reconsidering the design of mobile phones, and developing innovative educational interventions.

Keywords: Human-Computer Interaction for Development (HCI4D); Market Information Services (MIS); Affordance theory; affordances; agriculture; rural; Kenya

Introduction

Delivering pertinent information to smallholder farmers via mobile phones could help to address the economic development challenges of eradicating extreme poverty and increasing food security for sub-Saharan Africa's rural populations. Popular efforts to solve these problems include efforts by NGOs, technology companies, and entrepreneurial software developers to develop market information services (MIS). These SMS mobile applications are designed to provide rural farmers with pricing information

they can use to detect market opportunities, allowing them to sell their crops in markets that pay better prices and/or strengthening their negotiations with traders (Fafchamps and Minten 2012; Nakasone, Torero et al. 2014). Such mobile applications provide useful and practical information to some rural farmers, but not yet to those living in rural Kenya. Despite relatively high rates of mobile phone ownership throughout the country (Crandall, Otieno et al. 2012), and evidence from prior research suggesting that access to market prices can improve farmers' livelihoods (Nyarko, Hildebrandt et al. 2013), a recent report suggests only 5% of Kenya's smallholder farmers use MIS (infoDev 2013). We argue that limited adoption in rural Kenya can be attributed to a mismatch between the design of these systems and smallholder farmers' interpretations of mobile phones and their affordances, or the "properties of the world that are compatible with and relevant for people's interactions" (Gaver 1991). To assess this, we conducted observations and in-depth interviews with more than 70 farmers in western Kenya. We investigated their general mobile phone usage patterns and their interactions with MFarm, a commercially available MIS.

This study was guided by these two questions:

- What affordances do smallholder farmers perceive mobile phones to have?
- To what extent is MIS adoption hindered by farmers' perceptions about their mobile phones' affordances?

Theoretical Framework and Review of Related Literature

Gibson's (1979) theory of affordances provided a framework for examining smallholder farmers' mobile phone usage patterns. In this theory, the physical environment and an individual's perceptions are brought together to explain why people

perceive some technologies as being more intuitive to use than others. Central to this idea are affordances, or the actionable properties between the world and a person (Gaver 1991). People perceive objects in terms of the possibilities for action they offer, or afford, them: for instance, the shape of a coffee mug handle affords lifting, doorknobs afford turning, and the buttons on a mobile phone's keypad afford pushing. By examining an artifacts' affordances we can understand the different behaviors they can and cannot support. Although this approach is used extensively in fields such as Human Computer Interaction (HCI) and Cognitive Science to explain how technologies can be incompatible with people's actions (Norman 1983), to date there have been few attempts to apply this framework to studies of mobile phone use in developing regions.

This theory offers a powerful lens through which to examine rural farmers' understanding of the activities their mobile phones support, including SMS, the platform most MIS use. SMS supports sending and receiving short (160 characters or less) messages that communicate timely and simple information such as market prices to an individual. Sending a text message requires significantly less bandwidth than making a voice call, making this feature not only cheaper than calling, but also capable of delivering information to mobile phone owners in areas with limited network connectivity. Another major benefit of SMS is its interoperability. Mobile devices, from the oldest and most basic handsets to the latest smartphones, are all capable of receiving text messages. SMS is useful for services that require users to request specific information. By inputting a series of numbers and symbols (e.g., *100#) into a mobile phone, and then pressing the call button, a service can rapidly respond with information that corresponds to the characters entered (Hellström 2010). SMS's affordances have

contributed to the phenomenal success of M-Pesa (a Kenya-local SMS mobile money transfer service), and are central to the design of mobile applications that target long-standing problems within the economic development domain by providing people with health, educational or other pertinent information (Donner 2008; Kendall, Maurer et al. 2011).

MFarm: An MIS for Kenyan Farmers

MFarm is an MIS created by three entrepreneurial Kenyan software developers in 2011. Its creators have received international acclaim, garnered multiple awards and collected hundreds of thousands of dollars from donors. Online publications such as *WIRED* and newspapers like *The Guardian* describe the service as a "transformative" and "revolutionary" technological solution to development challenges such as alleviating rural poverty and increasing food security (Solon 2013; Tran 2013).

To use MFarm, farmers first subscribe to the service by texting the word "join" and then their name and location to a four-digit short code. Once registered, subscribers input, "price cropname location," and then 'send' it to this short code 20255. After the request has been submitted users wait for a response with a crop price from a chosen location, or market (Figure 1). The service offers daily market prices for 42 crops (including avocadoes, bananas, cassavas, mangoes, maize, and watermelon) for all of Kenya's five major agricultural markets (Nairobi, Mombasa, Kisumu, Eldoret, and Nakuru). Registering for MFarm costs 1 Kenyan Shilling (KES), about $0.01, and subscribers pay an additional shilling when requesting pricing information.

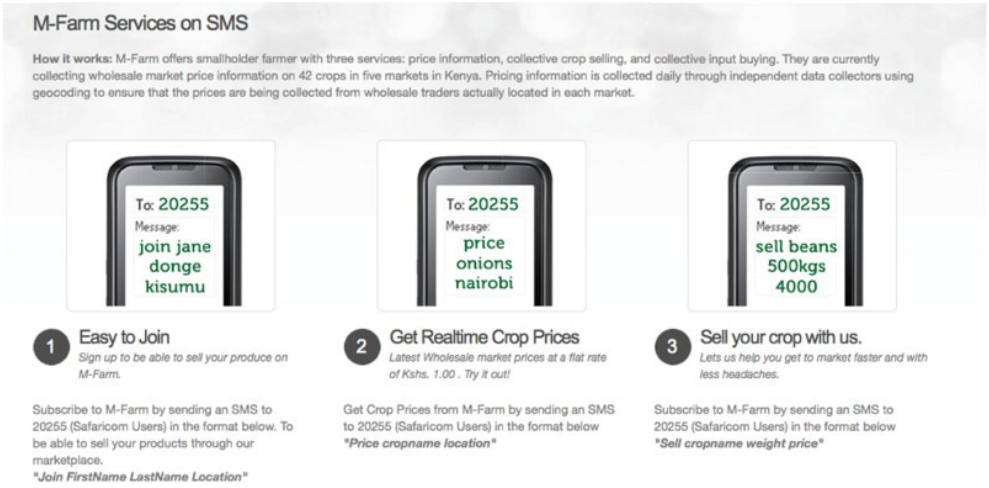

Figure 1. MFarm Service. Image taken from MFarm website (http://mfarm.co.ke/).

For MFarm's tech-savvy developers and other experienced mobile phone users, the system appears to provide farmers with easy access current market prices. However, there is a deficiency of research into the antecedent conditions necessary for MFarm and other MIS to succeed in rural Kenya, such as whether rural farmers understand how to use SMS to access market prices.

Analyzing the Impact of MIS

We identified one prior study investigating MFarm's impact on agricultural market performance; the researchers concluded "evidence on the utility of the information to help farmers obtain better produce prices is inconclusive" (Baumüller 2013). This survey-based study joins a growing body of literature devoted to quantifying the economic impact of text-based MIS on farmers; findings from these studies are mixed (Nakasone, Torero et al. 2014). Fafchamps and Minten studied whether the distribution of "agricultural information through mobile phones generates important economic benefits" in rural India, and found that access to pricing information did not significantly

improve farmers' ability to negotiate with buyers or receive more money for their crops (Fafchamps and Minten 2012). Likewise, Camacho and Conover examined whether text messages with detailed weather and price information improve smallholder farmers' welfare, and found that receiving price information via text message did not increase Colombian farmers' profits (Camacho and Conover 2011). Although these studies do not find that MIS positively impact farmers' ability to make more money selling their crops, results from other investigations suggest that economic benefits do come from using these systems.

In their impact evaluation of Esoko in Ghana, Nyarko et al. (2013) ask "Can MIS help farmers get higher prices for their production?" They found that farmers using the MIS sold their yams at 11% higher prices than those without the service. Ogutu et al. (2013) report that participating in "ICT-based MIS projects" had a "positive and significant effect" on Kenyan farmers, and encourage policymakers to expand MIS services in the country's rural areas. Goyal (2010) analyzed the impact of MIS on price variation by introducing *e-choupals* (Internet kiosks) to farmers in Madhya Pradesh, India. Findings from her study suggest that MIS increased soybean farmers' profits.

Results from these studies are promising, and suggest that rural farmers can benefit from receiving pricing information via SMS; however, these findings do not explain the low adoption of commercially available MIS in rural Kenya or investigate farmers' mobile phone usage (or non-usage) practices. Earlier studies of MIS have been predominantly carried out within the disciplinary tradition of economics, and lack a qualitative understanding of farmers' pre-existing mobile phone practices. Instead, they typically focused on groups of selected participants who already used the services under

study, and/or participants who had been trained, pre-evaluation, in how to use the systems (Goyal 2010; Nyarko, Hildebrandt et al. 2013; Ogutu, Okello et al. 2013). Although these studies are useful for understanding the circulation of information in markets, underlying their implementation appear to be assumptions that rural farmers understand the technical affordances of their mobile phones. Our qualitative study of rural farmers' and their initial experiences using M-Farm, was useful for revealing barriers to MIS adoption that cannot be easily identified in a controlled studies.

Indeed, it is this lack of research detailing farmers' everyday handset use, that is consistently described as a limitation of prior MIS studies (Duncomb and Boateng 2009; Lokanathan and De Silva 2010; Donovan 2011). Donovan writes that a consequence of this omission is the continued development of mobile interventions which fail to gain traction with farmers because their existing practices are poorly understood (Donovan 2011).

One notable attempt to fill this gap in knowledge includes Burrell and Oreglia's (2015) ethnographic investigation of Chinese farmers and Ugandan fishermen, which sought qualitative insight into why MIS have hitherto been unsuccessful. Their findings suggest that the market efficiency models underlying MIS are at odds with their participants' existing approaches to determining pricing information, and that such services rarely reach the poorest and most marginal subscribers in these countries because most require technical and language literacy. In another study, Molony (2008) interviewed Tanzanian tomato and potato farmers, and found that traders insist on farmers accepting one price for their crops even if the farmers have access to additional pricing information. We build upon these studies by examining how the technical

affordances of MIS differ from rural farmers' understanding of their mobile phones and the possibilities they support and by discussing interventions that may increase the use of these mobile services. Importantly, we also argue that prior to investigating adoption of MIS, or its economic impact, researchers must first ask whether rural farmers perceive their mobile phones as a source for agricultural information, or are even capable of performing the basic mobile phone operations necessary to access it.

METHODS

Qualitative research methods were among the first used in ICTD research, and continue to provide researchers with an in-depth understanding of the meaning, motivation, and overall context of human behavior surrounding technology use in developing countries (Toyama 2010). For data collection, we combined focus group, interview, and observation methods to investigate rural farmers' mobile phone usage and non-usage patterns, and thereby gain a better understanding of their perceptions of their mobile phones' affordances. We also frequently used MFarm during our time in the field, and conducted a user study of it; this involved asking participants to use their mobile phones to submit price information requests to the service via SMS.

Study Area

The study was conducted in rural villages in the counties of Bungoma, Homa Bay, Migori and Mumias in the former Western and Nyanza Provinces[1] in May 2013. These regions tend to be the most agriculturally productive in the country, and subsistence farming is the main economic activity for 80% of the residents (Homewood 2005). MFarm's developers also told our research team that farmers in these areas used their

[1] As of 2013, under the Constitution of Kenya, the countries eight provinces were subdivided into districts.

service. Finally, an author has been investigating mobile phone use in these regions since 2011; and her established connections with people in the regions, and with employees of local NGOs (e.g., One Acre Fund, ACE-Africa and the Animal Draft Power Program), helped the researchers gain access to sites and identify study participants.

Data Collection and Methods

Qualitative data were collected using group interviews and in-depth interviews with key informants, including MFarm's developers and staff at local NGOs working on mobile phone-related projects. The study population included fourteen groups, or 76 farmers (44 men and 32 women), who gave informed consent to participate and who had a mobile phone. On average each group consisted of seven farmers (range 5-12) selected by judgment or purposeful sampling (Marshall 1996). We selected smallholder farmers with mobile phones, because they would be most capable of answering our questions about using the devices to access information. Granted, this sampling approach has its limitations: for instance, our results are difficult to generalize to other smallholder farmers in rural Africa, and exclude people without handsets. However, considering the limited work investigating the usability aspects of mobile phone use in rural Africa, we wanted to begin with a diverse group of farmers from multiple sites in the Western region of the country. This allowed us to gain a descriptive understanding of the topic with which to inform what might be relevant issues for future research.

Semi-structured interviews were conducted in the language with which participants felt most comfortable speaking, and were moderated by the English-speaking American authors, with the assistance of two native Kenyans (one male and one female) who are both fluent in Swahili and English. Where possible, we interviewed men and

women in separate focus groups led by same-gender interviewers, to ensure that women's perceptions were heard. Men tended to answer questions in English, while women preferred speaking Swahili or their vernacular language.

Themes uncovered during our literature review, paired with the first author's knowledge of phone use in the region, informed the development of our interview protocol. Initial questions centered on mobile phones: specifically, farmers were asked how long they had owned the devices, and how they had acquired them. Farmers were then asked when they chose to make a voice call or to send a text message. This strategy of comparison revealed participants' reasoning for not using the texting feature embedded in all of their handsets. Another line of questioning focused on mobile phone use in relation to agriculture: participants were asked to recall the last time they used their handsets to learn about market prices. An important component of each session was digitally photographing participants' handsets: farmers were asked to show us their mobile phones so that we could document their make, model, and condition. The vast majority of our study participants reported owning phones, although we encountered participants who were unable to present them during the sessions for various reasons, including having left it at home, or at a vendor to have its battery charged. As compensation for participating in the 60-to-90-minute-long group interviews, farmers were given a Michigan State University t-shirt or 100 KES (about $1) of mobile phone credit.

MFarm User Study

At the beginning of our study, we had anticipated interviewing farmers actively using MFarm, and targeted areas where the service's developers told us we could find

subscribers. However, in only one of the 14 groups had anyone used the service, and they had stopped using it by the time of our interview. Farmers' inexperience with MFarm presented us with an opportunity to introduce them to the service and observe their interactions with it. We began the user study by describing MFarm, and then presented participants with laminated copies of the directions explaining how to use the application. Then we asked farmers to send an SMS to MFarm requesting a crop price from a nearby market. Over the course of our two-week study, we observed 57 farmers interact with the MIS.

Data Analysis

The authors began collaboratively analyzing data in Kenya to ensure that a sufficient quantity and quality of information was gathered. This initial analysis included writing field notes, and discussions among the research team about common themes. Once the interviews had been transcribed and translated, analysis was performed in the US. Standard techniques were used for extracting consistent themes in our data, including, reading and rereading field notes and transcripts and writing memos were used in our analysis (Glaser and Strauss 1967). We used these techniques to distill initial themes and conducted follow-up telephone and email conversations with research assistants to confirm our findings.

This analysis was not concerned with matters of quantification; instead, the claims made in this paper deal with rural farmers and their reasoning for not using MFarm, and aspects of their everyday phone use that are relevant for the design (or re-design) of technology (Salvador, Bell et al. 1999). Our interview and observation data provide a

thicker description of the challenges accompanying mobile phone use—evidence largely missing from earlier studies of MIS.

FINDINGS

A "Social Item" not an Information Delivery Platform

The vast majority of our study participants owned "dumb" models, such as Nokia 1280, Samsung GT-E, or Tecno T210 handsets; theoretically, participants could have accessed MFarm with those phones, but did not. Few used this and other MIS (i.e., Kenya Agricultural Commodity Exchange (KACE) is another commercially available MIS in Kenya), primarily because they perceived mobile phones to be devices that support verbal communication among their friends and family, rather than as platforms that delivers agricultural information in the form of a text message. Multi-country studies across Africa consistently show that mobile phones are used primarily to maintain individuals' social networks (Molony 2007; Murphy and Priebe 2011; Porter, Hampshire et al. 2012). In contexts of extreme poverty, social networks are vital to survival, and mobile phones represent important tools to strengthen these networks of extended families and friends (Carmody 2012). Rural farmers valued their mobile phones because they could use them to call someone in case of an emergency, such as needing help for a sick family member or being in dire need of cash. Using mobile phones to support these activities resulted in widespread perception of the devices as "social items." "Charles" [2], a sweet potato farmer living outside of Homa Bay, gave comments that captured many farmers' attitudes about their mobile phones:

[2] All participants' names have been replaced with pseudonyms to preserve their anonymity.

You asked something about mobile phones, we use them, I myself I use it. In the first case we were using them as a social item, maybe to pass this message to a friend, maybe to get some information from a family member.

We asked Charles and others if they used the devices to access agricultural information; a few men described occasionally calling "brokers" or middlemen when they had excess crops to sell. Farmers who were members of collective or co-operative groups rarely called brokers. Instead, a co-op member would make the call, then share the information with other group members at weekly meetings. Sambasivan et al. describe this as an 'intermediated interaction' and report that this practice is common in rural India (Sambasivan, Cutrell et al. 2010). Market information services like MFarm are not yet designed to support this interaction style, because they ask farmers to register as individuals, not as members of a collective.

Participants' descriptions of the button most commonly used on their phones, provided further evidence indicating that they interpreted mobile phones as devices that primarily support voice communication; this was particularly true for women. "Red and green button use" was a phrase they frequently used to describe making and receiving calls, an operation that typically requires pressing the red or green button on a handsets' keypad.

SMS Challenges

Their preoccupation with these buttons meant that farmers in our study rarely used the device's other keys, including those used to compose and receive text messages. While prior research relates limited use of texting to illiteracy (Medhi, Patnaik et al. 2011), and this was also the case in our study, farmers' use of SMS was also limited by

factors related to the mobile phones' design. Texting is difficult enough in English; doing it in languages such as Swahili, Bukusu, or Luo, which are characterized by imprecise spellings and very long words, is even worse. The multiple subskills required to send text messages via simple mobile handset—inputting letters, spaces, and symbols, and switching between upper and lower case—involve a significant learning curve, particularly when menus involve only English words. To make matters worse, keypads are cramped and awkward, sometimes requiring several key taps for a single character. The T-9 predictive text protocol was developed to make text entry more efficient for experienced users by reducing the number of buttons pushed; unfortunately, it confused farmers because the letters they entered rarely corresponded with what appeared on the screen.

Few women in our study had sent an SMS on their phones, telling us, "I don't understand much about the messaging," "maybe kids know, but not me," and "I don't know how to read a message". There is general agreement among researchers that women's lower levels of literacy and education are primary factors limiting their economic development and contributing to the gender digital divide (Stromquist 1992; Geldof 2011). Despite this, the developers of MFarm and other MIS continue to build text-based applications whose use requires knowledge of written English. Furthermore, even the participants in our group who did have experience with SMS perceived it as an unreliable communication channel: after a message had been sent, there was no guarantee that it would arrive at the intended recipient. The farmers contrasted this to voice calls, which result in immediate and guaranteed exchanges of information once the recipient

answers the phone. Jacob, a smallholder farmer living near Mumias, succinctly explained this phenomenon to us during a group interview:

You can send, but someone can just be silent, so it just makes you want to talk.

He added that recipients may be 'silent' if they are unfamiliar with how to access and reply to an SMS.

Affordances and Infrastructures

Farmers maintained meager amounts of credit on their mobile phones. A typical response to "How much airtime is available on your phone?" was "zero zero" followed by laughter. Men tended to have a bit more money—sometimes as much as 15 KES—on their handsets, while women were likely to have 0 to 2 KES. Although a voice call costs more than an SMS, farmers still preferred it because of the risk of sending (and paying for) a text and not knowing whether it would be received. The technical affordances of a mobile phone are tied to the amounts of credit which rural farmers maintained on their phones—a factor typically overlooked in industrialized contexts where the costs of using a technology are less central to its adoption.

In addition to credit, sending an SMS also requires that the handset battery be charged—a challenge in rural Kenya, where access to electricity remains woefully low. We encountered many farmers with handsets which had been turned off to "preserve the charge" —or which had batteries that were nearly depleted. Implicit in the design of services meant to deliver time-sensitive information via SMS is the assumption that subscribers carry a functional handset at all times. However, it was common for participants to have left their handsets at a charging kiosk, which could be as much as 10 kilometers from their homes. This significantly reduces the likelihood that farmers will

receive time-sensitive information while it still has value, further demonstrating the mismatch which exists between MIS design and smallholder farmers' perceptions of the communication capabilities of their mobile phones.

Material Properties of Mobile Phones and Other Ecological Factors

Widespread perception that mobile phones support voice communication rather than textual may help explain why farmers in our study were not using MIS to access market pricing information. We discovered other factors which contributed to limiting farmers' use of texting—in particular, the quality of participants' handsets, and the environments in which they are used. Farmers in our study tended to own mobile phones which showed considerable wear and tear after four of five years of use; some phones even had rubber bands holding their rear panels in place. We observed screens that had been cracked by falling on concrete or hardened dirt floors. Many keypads had numbers which were faded or completely worn off (perhaps as a result of over-use and/or overexposure to the elements), and some of the poorer-quality "China-makes" had lost buttons entirely. Screen parallax (the displacement in the apparent position of an object viewed along two different lines of sight) was common due to the harsh sunlight (Rogers and Graham 1979). Participants used their hands to shade the screens on their phones, because reading text on the devices was difficult to do outdoors on sunny days.

Participants also had difficulty reading content on dimly-backlit phone screens while in houses with inadequate illumination. Another complication to texting was that farmers typically had poor eyesight, a common consequence of living in off-grid settings where fuel-based lighting is the norm (Kittle 2008). It was typical for participants to squint and hold their handsets as close to their eyes as possible when reading information

from the small screens. Prior studies cite poor lightning conditions, and rural farmers' inability to afford glasses, as reasons for widespread limited visual acuity among this population (Burke, Parel et al. 2006), but few studies have related these conditions to mobile phone use.

Similar to Crandall (2012), we found that the habit of sending and receiving a text message is not widespread among rural Kenyan farmers due to reasons described here, including perceptions that inputting text is cumbersome. Our research highlights additional understudied factors that may also contribute to limited SMS use, in particular the materiality of the phones farmers own, and the rural environments where the devices are used.

Figure 2. MFarm Responses on Mobile Phone Screen

MFarm Usability Test

During our fieldwork, we encountered nine farmers who had used MFarm. The majority of our participants' unfamiliarity with the service presented us with an opportunity to deepen our understanding of their mobile phone usage practices, by observing them send an SMS. At the end of each group interview, we provided participants with the short code needed to use MFarm, and observed them painstakingly enter queries into phones, such as "price watermelons kisumu." We then waited seconds, and depending on the quality of the mobile phone network, sometimes minutes for the

phone to beep and buzz, indicating the arrival of a new message. During this process, we watched them type “Nalrobl” for “Nairobi” and “Eidoret” for “Eldoret” —errors caused not by misspelling, but by the inability to distinguish between “i” and “l” on the handset's small screen.

Even when participants did correctly enter the name of a crop and a market town supported by the service, a third of the responses were statements that the requested information was unavailable (see Figure 2, left). For smallholder farmers, the financial costs of sending a text message are significant, and receiving a useless answer was disappointing and confusing. A natural question related to the use of MIS is whether the expected benefits are worth the cost (Donovan 2011); findings from our limited observations suggest this might not be the case, particularly if a 1 KES expense results in a useless response.

Our conversations with the nine farmers who had used MFarm highlighted additional usability issues to consider when developing MIS. The farmers told us that they had used the service two or three times prior to the interview, having learned about it when one of the service’s developers led a workshop for their sweet potato cooperative a year prior to our interview. Unfortunately, after multiple months of having no sweet potato surplus, the farmers forgot the code needed to use MFarm, and had to stop using the service, supporting the conclusion drawn from prior research that memorizing short codes does not come intuitively to rural farmers (infoDev 2013).

DISCUSSION: AN ECOLOGICAL APPROACH TO DESIGNING MIS

Returning to the research questions posed in our introduction, our results are consistent with prior studies which demonstrate that owning a mobile phone does not

necessarily lead to use of its text-based features (Medhi, Patnaik et al. 2011; Crandall 2012; Dodson, Sterling et al. 2013; Velghe 2013) and that the conditions surrounding phone use affect the uptake of pricing information (Srinivasan and Burrell 2015). Mobile phones, despite widespread ownership among Kenya's smallholder farmers, are new devices our participants are still learning to use, and they are not yet taking advantage of all the services that the phones afford. This factor, in combination with lack of airtime, uncharged handset batteries, old phones, and poor eyesight, suggest that the affordances of MIS are at odds with farmers' understanding of their device. Our findings also reveal how farmers' abilities to take advantage of the services offered by mobile phones are complicated by the phones themselves, and by the conditions in which they are used. Here we use these findings to motivate a design agenda that encourages software developers and development practitioners to adopt an ecological perspective when developing SMS-based services. By this we mean accounting for the confluence of farmers' knowledge of their phones, their financial realities, the material qualities of their phones and the broader infrastructural and environmental factors affecting mobile phones in rural Kenya.

Reconsidering Mobile Phones

Our participants' phones were in such poor condition that SMS was much more difficult than MFarm's developers and designers had expected. Indeed, well-designed mobile services and applications are of little use if the devices that support them are not suitable for rural conditions. Preferred solutions include more durable phones with larger screens, and longer-lasting batteries, as well as handsets that default to Swahili, and straightforward modes of text entry rather than T9. We also recommend that keypad

buttons have raised lettering rather than the silkscreened lettering we observed on participants' handsets, as the latter rubs off too easily. The developers of SMS-based applications should explore content delivery in their subscribers' primary language. Power grids also need to be improved in order to realize the full information dissemination potential of the mobile phone, as does farmers' ability to purchase airtime.

These are ambitious long-term goals that we complement with more immediate recommendations. The MFarm system already corrects commonly misspelled crop names and market towns, but does not take into account homoglyph errors caused by difficulty in distinguishing characters on the phones' keypads (for example, "i" and "l"). Responses to queries should include price information from multiple markets, rather than a single one, so as to reduce the chances of receiving a null response for a given crop/market combination.

Our findings also prompted us to question the necessity of asking farmers to register for these services. Registration processes, like the one currently implemented in MFarm, contrast with our observations of farmers' desires to share pricing information with other members of a collective or co-op. More problematic is that, among rural farmers, ownership of mobile phones and SIM cards can be quite fluid: handsets break, or are lost, or stolen, or resold, or given away. As a result, farmers must constantly re-register for services—and re-pay to do so. However, a benefit of registration is that service providers can track users, and (as with the sweet potato farmers we encountered) send them reminders about the service when it has not been accessed for a long period of time. We recommend that MIS developers account for these trade-offs when designing their systems, as forgetting a short code may result in farmers no longer using a service.

Perhaps text messages are not the most effective medium for communicating with rural farmers. Indeed, prior HCI research projects offer alternatives to texts for people who prefer to communicate orally rather than textually; for instance, Avaaj Otalo (Patel, Chittamuru et al. 2010) relies on personal and pre-recorded voice messages to convey information to farmers. Future research is needed to determine whether voice-based MIS will benefit Kenyan farmers.

Innovations in Education

We hesitate to assume that merely implementing these design changes will be enough to increase MIS use among Kenya's rural farmers, because such recommendations invoke a technological deterministic perspective (i.e., perceiving technology as an autonomous, external force imposing societal change) that overlooks other factors affecting not only the use of MIS, but also whether farmers can even benefit from the information. Continued efforts are necessary to understand whether farmers trust pricing information that comes from these services (Molony 2008), and whether the economic models underlying their development are at odds with farmers' current marketing and selling practices (Burrell and Oreglia 2015; Srinivasan and Burrell 2015). By adopting an ecological perspective when designing MIS, we see that innovations must not be solely technological; educational innovations are also necessary. In our ongoing research, we are adopting and implementing the successful "Digital Green" approach to teach farmers about the communication affordances mobile phones provide.

The Digital Green project, launched in 2006, is an example of creatively using video to disseminate educational content to rural farmers. Video segments are produced in a participatory process in villages using pocket video cameras, and shown locally with

small, mobile projectors. We will replace agricultural content with information describing the benefits of SMS, and that show viewers how to effectively send a text and/or change the input mode on a handset. These are basic handset management skills all rural residents seem to want to know. Central to the Digital Green approach is having experts relate the information to viewers; members of the MFarm development team could take on a similar role in these videos. Evaluation of this approach suggests that disseminating targeted information to smallholder farmers via tailored videos increases adoption of new agricultural practices in rural India; we speculate this may also increase Kenyan farmers' technical literacy (Gandhi, Veeraraghavan et al. 2009).

One could argue that, with time and increased exposure, rural users will become more familiar with their mobile phones and their affordances. However, as smartphones become more common in rural areas, new usability problems will emerge, such as how to correctly enter a query into a search engine or take a digital photograph of a blighted crop. As mobile phones in rural Africa continue to evolve from simple communication tools to service delivery platforms, educational interventions must accompany the introduction of all new services and applications.

CONCLUSION

Based on findings from in-depth interviews and observations of more than 70 Kenyan smallholder farmers, paired with a user study of MFarm, our paper describes the mismatch between the design of MIS and farmers' perceptions of the affordances of mobile phones. We demonstrate how affordance theory draws attention to ecological factors that are central to the use and adoption of MIS, but that have been largely overlooked in prior controlled studies of these systems, such as the quality of farmers'

handsets and the environment in which they are used. Our research also provides nuance explaining the mixed success of MIS, and offers some strategies—educational and otherwise—which may result in greater use of these services which have proven beneficial elsewhere in the developing world.

The findings presented here are based on short-term fieldwork; it is understood that longer-term ethnographic research can be conducted to deepen our understanding of rural farmers' perceptions of their mobile phones. Further, the study was largely exploratory and, as such, does not claim to statistically represent rural Kenya; however, the findings shed light on practices that are likely not uncommon among farmers in sub-Saharan Africa. Additional efforts are also needed to evaluate the impact of the design recommendations presented here. We conclude that attempts to develop MIS and other SMS-based services in rural Kenya, if based solely on the technical affordances of mobile phones, will fail. Designing successful systems demands greater attention to the broader ecosystem in which mobile phones are used, as well as new interdisciplinary perspectives combining economics and HCI.

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