Practices and Technology Needs of a Network of Farmers in Tharaka Nithi, Kenya

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ABSTRACT
Farmers in rural areas of Kenya generally rely on traditional agricultural practices inherited from past generations. However, population increases and climate changes have put pressure on resources such as land and water. These resource pressures have created a need to broaden and expand farming practices. We conducted an exploratory study with farmers in Tharaka Nithi, Kenya to explore their practices, if and how they used ICT, and how the technologies used might be designed to aid their practices, if at all. Overall, our results show that farmers desired more knowledge to enable them apply ICT interventions in ways that improved yields. Farmers were also interested in accessing information on soil fertility, water predictability and market opportunities.

These findings suggest opportunities for technology design to support farming practices among rural communities in rural settings. We also articulate social challenges that designers will face when thinking about coming up with such solutions.

Author Keywords
Farmers; mobile phones; rural farming; farming technologies.

ACM Classification Keywords
H.5.m. [Information interfaces and presentation] Group and Organization Interfaces - Computer Supported Cooperative Work.

INTRODUCTION
An extensive amount of research has documented the various challenges experienced by farmers in developing countries as they look to feed communities and generate income [33,37]. This body of work reports on the pervasive infrastructure and social challenges faced by farmers such as shifting regional food preferences, small-scale land ownership and use, the need for efficient irrigation practices and the need to improve crop productivity in rural communities [39,41]. To meet a rapidly growing demand for food, improvements in land and water management, crop productivity and resource-use efficiencies will be required [41]. Economic difficulties and lack of markets have also been reported to hinder rural farmers in their attempts to gain meaningful income from routine farming activities [1]. Other work also reports on how rural communities in developing countries use technology to share information among farmers with the intention of learning better processes from seasoned peers [19,30]. Beyond information sharing, and applying technology to collect data [45,46], there seems to be little research on how insights from farmer practices around technology use in rural communities of developing countries, could inform the design of technology that can support rural farmers achieve their perceived goals [16].

Our research builds on the existing literature to address this gap. We investigate rural farming practices to unearth areas where technology is already being used and report on technology needs beyond information sharing and the use of data to inform farmer decisions [45]. Thus our work goes beyond already documented challenges faced by rural farmers to improve yield and search for markets for their produce [25]

We conducted an exploratory study with 27 rural farmers living in Tharaka Nithi (Figure 1), Kenya [43]. We explored how farmers selected crops, decided on methods for cultivation, and shared knowledge with their peers and government institutions to make informed decisions. Within each area, we sought to understand the challenges farmers faced; when, how, and why they used technology; and, what challenges they felt could be addressed with new technologies. We make two major contributions with this study for the HCI community. First, our work enriches the HCI4D literature on understanding the practices and routines of rural farmers around the use of technology. Second, we describe implications for future research and design where we raise questions around how designers might open up new opportunities for incorporating systems that provide knowledge, advice and interaction opportunities that foster avenues for coordinating activities to farmers in developing countries. We focus our discussion

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CHI 2018, April 21–26, 2018, Montreal, QC, Canada. © 2018 ACM ISBN 978-1-4503-5620-6/18/04...$15.00.
http://dx.doi.org/10.1145/3173574.3173613

on the way a group of farmers who belong to an irrigation scheme use technology to support farming decisions and illustrate what areas designers will need to explore when creating or deploying technologies that support farming in rural parts of Kenya.

RELATED WORK

Background information leading to our work

Extensive research on the role of ICTs in agriculture report the use of ICTs to improve productivity through informed farming practices. The use of interactive technologies in urban farming networks suggest opportunities for leveraging interactive systems to potentially support more sustainable ways of living in urban areas of developing countries [26]. In developing countries, investigations have been conducted on practices that lead to exceptionally high levels of agro - sophisticated practices that gravitate towards maintaining exceptionally high levels of agro-diversity. For example, an investigation in Hamisi, Kenya revealed that population pressures jeopardized diet quality and food security since most families were highly dependent on market purchases and less on nutritional values that agro diversity was geared towards [9].

Mobile phones have been reported to increase income, improve the efficiency of markets and improve service delivery. However, their effectiveness still require other infrastructure such as the Internet to be in place before their full potential can be achieved [11,31,32,38]. Still, we are able to identify several examples of the adoption of the available technologies in farming. In rural Uganda, farmers stored market information in their phone calendars, took and shared photos of agricultural demonstrations, and even used the speakerphone for group conversation when consulting with aricultural experts. Even though access to mobile phones has improved among rural farmers in marginalized economies, the rollout of extension programs though ICTs is still in an early stage, and little research is available regarding the impact of such programs [15,24]. These studies show promise for the exploration of ways through which ICTs can support farmers in rural sub-Sahara Africa to adopt farming practices that are informed by insights from data gathered using technology, in addition to existing farming practices that farmers currently use [45].

The use of video content developed by farmers in marginal settings while working with experts via participatory process for content production has also been explored [2,13,37]. The lure of appearing on video while engaging with experts on discussions around farming practices was found to be more appealing to farmers in comparison to classic Training and Visit-based (T&V) extension approaches [2,13]. Other video based farming programs have been applied in local settings to share knowledge between farmers and agricultural experts. In its initial year, a TV program in Kenya called Shamba Shape Up, that demonstrates practical agricultural solutions to farmers via visits to farms around the country influenced 36% of respondents to reconsider their current farming methods [36].

Even though ICTs provide farmers with an opportunity to share farming practices with each other, they can also act as hindrances to efforts aimed at designing solution that are inclusive to women especially in rural populations [17]. Studies have revealed that the complexity and heterogeneous nature of gender roles within African households and communities are dynamic and respond to changing economic times that impact technology usage within these communities [12]. Therefore, the role of technology and gender in crop management systems is an integral point that should be considered as it can influence technology adoption in rural communities of developing countries where a big percentage of women reside [8,29,37].

A divide remains when low income farmers are compared to their more successful counterparts. This implies that technology approaches to farming in marginalized economies should always consider economic and gender disparities [8,24]. Through participatory design with rural and low income farmers in developing countries, we can attempt to address challenges raised by past studies on low resource farming. For example, [45] reported that farmers in rural settings lacked clear mental models for using technologies to support their farming activities [45]. Participatory sociotechnical design approaches can be applied in rural communities while exploring the design of solutions that aim to address problems around agriculture as seen from the perspective of local farmers [34,35]. This way, stakeholders working together in rural and low income farming communities can all feel involved in solution design and eventually embrace the design outcomes with enthusiasm [6,7,10,34,40].

The work covered in this section highlights the importance of gender, digital access disparity, and the opportunities provided by ICTs as key factors that can shape the design of appropriate technology for use by farmers in rural communities of developing countries.

Policies and Regulations

Technology has also been reported to improve various aspects of farming such as income generation and diet enrichment in developing countries. For example, income for various farming households in Rwanda composed of various educational and social backgrounds improved as a result of using farming technologies such as green manure and diamond phosphate in addition to government support [4]. Extending policy application to technologies that influence fertility regeneration, rural welfare and food security should be pursued for local communities to maintain momentum in areas where government interventions offer hope [3].

However, most small-scale farmers face financial limitations and are not able to invest in such technologies,

thus prompting intervention from larger and more capable entities in the form of investment. This problem can be tackled with the support of agencies that work with local farming associations already enmeshed within rural communities to advocate for investments in infrastructure and technology solutions.

Policies that foster innovation and technology diffusion can also help address adverse effects of climate change due to already prevalent low agricultural productivity and widespread poverty [18]. Such policies could guarantee basic training on accessing and using a minimum level of technology knowledge to share information among low-income farmers. When implemented alongside agricultural technologies that manage water and irrigation, marketing and production, such policies can create support for farmers in rural communities [18]. To support farmers in analyzing their trends around production, policies could be realigned to allow community leaders to gather farmer data from their mobile devices. Analyzing this type of information provides insights on farming practices. Armed with the gathered user data, policies can then be used to target social programs or even promote yield technologies by improving farmer access to these platforms via hands-on training [18]. The work discussed in this section provides insight into the opportunities for using technology to gather farming and climate data information in ways that can support rural farmers make more informed decisions. We discuss our study process and results next.

ICTs, Collaboration and Division around access to Resources and Markets

ICTD research often treats communities living in rural areas of developing countries as relatively tightly knit entities around family, ethnic, religious or clan associations. This assumption has led traditional technology interventions towards the adoption of overall goals that aim to benefit such collective groups. A separate set of studies [6,34,35] pushes designers to avoid the single solution-fits-it-all mentality while thinking about crafting solutions for rural settings of developing countries. Designing collectively for a group of users risks empowering the elite based on perceived harmony that can potentially lead to the neglect of non-empowered participants and non-adoption of intended solutions once rolled out [10]. Designers and researchers are therefore advised to recognise the political nature of the investigation methods applied to gather information, and also aim to build capacity of the local communities with a long term intervention plan based on limited imposition of external influences [5,10,16]. Proper researcher preparation for field studies with consideration for practical, methodological and ethical issues should aim to capture community feedback throughout the research project. The creation of an effective workspace in addition to reliance on local facilitation can create user motivation and interest on the part of the intended users [6,14]. A considerate approach that resonates with how the local communities understand their living situation should be thought out while setting scope of the project [6,34]. The investigation should also appreciate the political nature of the research method applied while looking to build capacity of the community with the intention of a long term intervention based on feedback from the community. Last, ethnographic procedures geared towards understanding users should aim to transcend gaps between the participant and interviewer and provide a strong foundation for good HCI4D exploration [5,14,34,35,37].

STUDY METHODOLY

We conducted an interview-based study with rural farmers in an effort to: (1) understand their current farming practices while using technology, and (2) to gather insights that will help inform the design of future systems that support farmers in making informed decisions.

Figure 1. A map highlighting our study location [44]

Study Site

Our research was conducted in Mbogoni irrigation scheme in Tharaka Nithi which is situated 175km from Nairobi. The population of this region is approximately 365,000 and the main economic activity is subsistence farming of fruit, vegetables and the raising of dairy cattle. The region is in a semi-arid part of Kenya and borders Meru county to the north, Kitui county to the east and south east and Embu county to the south. Mbogoni irrigation scheme has 500 farmers distributed across a 100 ha land and plant a variety of crops that included bananas (covered 48% of the land), kales (12%) and tomatoes (10%). Other planted farm produce includes passion fruit, sweet potatoes, cabbage, onions and water melon. The land is divided into four blocks/regions with equally the same number of farmers in each. The farms sizes range between 0.5 acres for the low income population and 37.1 acres for farmers on the other end of the spectrum. Small-scale farms predominate the area with 76% being less than 5 acres in size while medium-scale (>5 acres) farms cover 24% of the region.

Participants

We recruited 27 farmers (23 males, 4 females) aged between 25 and 65 years with about 40% of this population aged above 55 years and retired from formal employment. Of the remaining, 60% had high school education and some type of college training while the rest reported not having attended any formal educational institution. Technology savvy farmers (4) accessed the Internet (using their mobile phones) to acquire knowledge about ideal farming routines but mentioned that they had actually not implemented such knowledge in their farming routines. For example, a farmer reported that he was familiar with Facebook and Twitter but had not actually used these technologies in relation to his farming activities. Approximately 21 farmers used their mobile phones to coordinate farming related issues with 13 farmers reporting the use of basic Android phones. Participants were identified through purposive sampling conducted with the help of the secretariat of the irrigation scheme.

The secretariat, which consisted of farmers selected to run the office and coordinate activities for the remaining members of the irrigation scheme, used their understanding of the farming area alongside our research questions to select five farmers from each quadrant block. The blocks consisted of farmland that contained different types of soil and different sizes of land ownership per farmer. Family composition was also different in terms of the participant ages and number of family members per household. The smallest number of heads per household was 3 while the largest was 10. Participant recruitment was iteratively conducted to ensure that all possible farmer types, farm land, type of crops planted, and animals reared were captured. The total number of women who responded to our questions was about 12, but due to family structure dynamics, interviews that involved couples were recorded under the male participant's name. When both a female and male participant were present for interviews, we ensured that the woman was always provided with the opportunity to share her views with either the principal investigator or one of our female team members.

Interviews and Home/Farm visits

Our research team consisted of 2 males, 3 females. 4 of the researchers were Kenyans while 1 was Caribbean and an expert in Water and Agriculture. At the time of our investigation, the first author had lived in Kenya for a combined period of ~25 years. Besides this work, the first author conducts HCI4D research in user practices around water management and use in remote parts of arid and semi-arid Northern Kenya. The first author also explores technology use in the management of hypertension in rural parts of Southern Kenya which also happens to be his ancestral home. Experiences gained through these projects not only gives us an understanding of how to create strong connections with the communities we work in, but also provides an opportunity to provide insights that are difficult to achieve via short study periods that characterize ICTD research. Prior to this work, we oversaw a water monitoring project in the current study setting, after which, we gave the sensors used during the study to the farmers and continued to provide them with advice. We also participated in social activities within the community, e.g. attended a pre-marriage ceremony, frequently tea and fruits whenever possible while conducting our studies. The local administration and village elders also praised our work with the local farmers during public meetings conducted in the community. To reciprocate, we constantly invited the local administration alongside the irrigation scheme secretariat to group meetings. We would keep them informed about our work continuously and this showed them that we were concerned about the community and not just outsiders simply interested in studying them.

Figure 2. Close view of sprinkle irrigation in a farm

Data Collection

We used a combination of methods that included, participant observations, contextual inquiry and field investigations to gather participant responses over two visits. Participants were provided with a consent form that described our research interest and also informed them that participation was voluntary. Each farm visit lasted between 45 and 60 minutes. During the first visit, we conducted an in-depth interview with the participants about their farming practices. Participants were asked a series of questions about what they considered their occupation to be, how they determined what to plant, the motivation for their farming and the role technology played in their farming activities. We also asked the participants to highlight the challenges faced during their routine activities and whether they already used technology to address these challenges. The fluency of the Kenyan research members in Swahili and Sheng (slang) facilitated open conversation with our participants. An iterative data analysis was conducted with our larger team where both male and female team members brought in their input based on their various expertise.

On completion, a second visit by the lead author and another team member was conducted approximately six weeks after the initial visit to confirm whether the interpretation of our responses reflected participants' original accounts. During the first visit, all the farmers were interviewed within their homes and around the farms that

were located inside the home, while the second visit mainly involved discussions around clarification of our interpretations as we observed the farmers go about their routines in both settings [7,23,43,35,].

On completion of the study, participants were rewarded with Kshs 1000/= (≈US$ 10). Overall, our participant selection gave insight into the practices of rural farmers who applied various types of farming practices on variety of crops to achieve the best possible yield. We were also interested to determine if, and when our participants used some type of technology in their farming activities.

Analysis

We kept photographs, handwritten notes and audio recordings of all interviews. The audio files were transcribed to better code the data and to organize illustrative examples of code pieces. We performed thematic analysis of the study notes and a coding process on all of the interview data [43]. This analysis involved categorizing participant responses using open and axial coding, and then drawing out main themes with selective coding, performed by multiple researchers on the project after reviewing the generated codes [42]. Our high level coding categories related to the types of activities that were performed by the farmers to determine which crops to plant, how the farmers learnt about new methods from their peers, the ways people tried to mitigate challenges around accessing water and fertilizers, and exploring markets for their produce. For each of these categories we tried to determine whether technology usage was involved during the associated activities. We report on our study findings next. Participant quotes are listed with a P#.

REASONS FOR USING ICT

Technology as an Educational channel

Like [13,19,30], our studies corroborate earlier findings that farmers use technology to share information with their peers, family and experts to gather agricultural related information. In addition, our participants used technology as a platform for training and learning.

Farmers used their mobile phones to set up meetings with agricultural extension officers when they required expert feedback on plant diseases that past methods were not able to address. Farmers would set up meetings with agriculture experts, as the experts performed routine bi-weekly meetings with the irrigation scheme farmers at the secretariat. These side meetings provided farmers with an unofficial avenue of interacting with the officers without the hassle of detailed planning. Past studies report that farmers have shared plant images with agricultural experts in the past to get feedback as a form of diagnosing plant diseases [19]. In our case, the farmers would place a quick phone call or text message informing the officers of the intention to meet briefly once they completed their routine meetings at the secretariat. The phone calls would be made from a week up to a day or two prior to the experts visiting the irrigation scheme. Once granted, some farmers would cut an infected plant and carry it with them and show it to the expert. By doing this, the farmer would have their issue addressed on the spot as opposed to when a photo was forwarded to the plant doctor as reported in [19].

Our participants reported that whereas it was recommended to seek professional advice from experts, they eventually had to rely on their own judgment to make the final call. One approach was via knowledge gathered from national radio programs such as Kilimo Biashara on a national radio channel. The program usually discussed new farm products such as fertilizers that the farmer would purchase at the Agrovet for farming [3]. Another group of low earning farmers within the irrigation scheme listened to a local Meru radio station that addressed current challenges by inviting farmers as speakers as reported in [31].

Newspaper information also acted as a source of Knowledge for another set of farmers who generally relied on trial and error farming practices gathered over time. P4 told us that

"*I read newspapers to gather information that could improve the yield in this farm even though I mostly know what I need to do based on experience in case I encounter challenges while farming."* P4.

In addition, P19 told us that he read the Saturday Nation to keep up with latest advances in agriculture.

"*The Saturday Nation (Weekend edition of Daily Nation) has a segment that features best practices in farming, success stories, careers in agriculture and contacts of potential buyers and sellers.*" P19.

Figure 3. A farm showing banana plants, vegetables and trees

Guidance and affirmation of good cultivation practices

Our participants generally practiced crop rotation by planting crops such as maize after beans in case the yield of either crop reduced in subsequent yields. Widespread use of fertilizer and manure was reported as a major part of ensuring that quality output was obtained from crops. Over 50% of farmers mainly applied one type of fertilizer during planting and topped up with another at a later point when the crops started to be stunted. Over time, farmers began to prefer particular types of fertilizer to others. For instance, 5

farmers reported the use of Diamond Phosphate (DAP) fertilizer while planting maize and tomatoes with P1 reporting that he avoided the use of Nitrogen, Phosphorus and Potassium (NPK) 2323 fertilizer since it made crops unhealthy based on experience. The plant doctor also advised the farmers on the effectiveness of different types of fertilizers whenever they enquired.

Farmers also reported the mixing of manure and fertilizer during cultivation with the expectation of obtaining good crop yields. The agricultural experts (plant doctor, extension officers, more successful farmers and Agrovet) took the roles of providing solutions to challenges raised by farmers. We also found that there was a general feeling among the farmers that the government officials mainly provided theoretical advice that did not work in practice. Farmers who were economically not at the level of their more learned and financially stable counterparts also felt that some of the fertilizer recommendations provided by the experts were too expensive. This set of farmers generally relied on experience to make decisions but occasionally when things did not work well in terms of plant health or expected yield, they looked for advice from other fronts. Tradition farming methods encouraged the used of manure, crop rotation and advise from successful farmers when one was confronted with decisions to make regarding soil fertility and the types of plants to cultivate (Figure 3).

In case things did not proceed as planned in terms of plant yield, such farmers would follow up on the issue of soil fertility by seeking advice from radio programs, newspapers and finally the agricultural experts as described by P26 below.

"*the sources of support include government agricultural experts who generally provide sound but impractical advice' Radio programs are important to me as I have learnt about new hybrid seed varieties and new fertilizers by listening to Kilimo Biashara radio program*" P26.

P27 also reported the use of technology as described below

"*I watch farming programs that cover fruit growing on TV and this has helped me tend successfully to the fruit trees that I have in my farm*." P27.

Other farmers also used radio programs to corroborate information that had been gathered over time but not yet proven, to support their choices on what to plant. For example, P19 confirmed his fears that fake hybrid seeds were being sold in the market after a local farmer shared his story on how his own hybrid seeds yielded nearly twice what P19 produced in the same portion of land.

Access and Distribution of irrigation water

Availability of water was a major determinant of when to begin the farming process and also influenced when particular type of plants that would be planted. Early rains began in mid-April while late rains started in mid-October. Water plants such as maize, beans and tomatoes would be planted at the beginning of the rainy season. Other plants that required more water such as coffee would be planted during the dry season so that by the time rains came, they would already be grown and benefit most from the rain. Farmers also relied on radio weather forecasts to know when the rains would eventually come in case there were delays in the onset of the rainy season.

Our participants practiced drip, sprinkle and overhead irrigation depending on an individual farmer's preference. Generally, drip irrigation was practiced by farmers who avoided the tilling of land as only the plant would be watered while the weeds around it would just dry out (Figure 2). Small farm owners who conducted most of the farm work applied drip irrigation as this also enabled them to free time to conduct other farm related work. To ensure maximum benefits from the drips, some farmers would open the drips at night for the soil to retain moisture as opposed to doing so during the day when the water would quickly evaporate.

Because the water pressure around the scheme was different, a set of farmers could not apply drip irrigation by virtue of the location of their farms along the irrigation water line. Some farms along the irrigation lines constantly experienced low water pressure and adopted sprinkle and overhead irrigation whenever water was available. However, those who practiced drip irrigation were critical of overhead irrigation, as they believed that it caused soil erosion and increased land infertility that led to poor yields.

Generally, farmers did not report the use of technology to seek information around access and distribution of water beyond seeking clarification and following up with the secretariat whenever they felt water was not being rationed fairly. Thus, mobile phones were used to call the secretary whenever there was a water related complaint to be raised. Usually the complaints would arise when a farmer got information that some participants in the scheme received water unfairly. (i.e. for three days a week instead of the official two days. P8 had this to say regarding this issue

"*sometimes we get calls from some farmers about tampering with how the rationed water is shared among farmers in the scheme. When this happens, it affects how much water we receive and so we will call the secretary to verify such information."* P8

Coordinating market opportunities

Research has extensively covered the use of technology to support farmers in developing countries in exploring markets for their produce [11,36,19, 24. The studies focus on mobile phone based solutions rather than investigating the relationships between various networks within a group of farmers such as in our case. In our study, we highlight how social challenges that farmers in the same irrigation scheme faced. We found that inequitable sharing of irrigation water, buyers towards the formation of farming networks when approached by potential buyers and general

lack of motivation affected the potential for farmers to access rewarding markets for their produce.

Farmers used mobile phones, information gathered from both radio and newspapers and even communication with their relatives to seek markets for their produce. Radio programs such as Kilimo Biashara provided information about the price of farm produce in nearby towns. However, such opportunities remained distant for low income farmers since suggested interventions that could produce high yields were already expensive to implement during cultivation.

Lack of farmer cohesion resulted in disjointed approach to marketing. Farmers grouped themselves based on allegiances rather than an overall goal that would benefit the wider irrigation scheme. For example, a group of five farmers reported that they were already in talks to plant barley for the upcoming farming season since they had received information that it could sell at better prices in slightly further markets. Discussion of such opportunities were generally carried out via mobile phones between a go between contact, a small group of farmers and potential buyers. Even though it was common knowledge that broker prices were exploitative, the low income farmers such as P 24 felt it necessary to cash in on the opportunity as they already felt unappreciated within the irrigation scheme.

When asked about why she was not enthusiastic about the irrigation scheme and why she preferred to work with brokers, P24 had this to say; -

"*even though I am supposed to get water at least twice a week, there are occasions when it does not come at all. No one has ever answered me…the agriculture officers recommend expensive solutions without coming to my farm. This is why I prefer to work with brokers as they guarantee some level of income.*" P24

Unlike the low income farmers who basically relied on brokers and the local markets to sell their produce, successful farmers were able to sell their produce in slightly further markets and were able store their produce while doing this. A set of successful farmers looked to cultivate only produce that the brokers were not interested in as this was a more profitable venture as P6 reiterates below.

"I *do not work with brokers since they are not willing to buy produce at realistic prices. I cultivate crops such as tobacco that can only be sold to BAT depots. In other cases, I will call my friends who live away from our village to enquire about current prices of farm produce. Once I hear about better prices, I head over there to sell my produce and this is usually in places like Ishiara, which is located about 40km away.* P6.

Still, even the more successful farmers mentioned that they faced challenges whenever they transported their produce to distant towns. The local government through the chief's office organized barazas to sensitize the farmers about the need to partner among themselves for good cause. Similar to [8], we find that a certain economic, social or preferential divide remains when low income farmers are compared to more successful counterparts. These divides could have easily created unwillingness among the farmers and the secretariat to work together in an inclusive manner for a common goal.

In an attempt to address this, the scheme put effort into training the farmers on contracts by bringing in experts who provided training at the secretariat. The trainings were done via a curriculum that incorporated various technology. Some of the technology include video demonstrations that were projected to the wall, discussions and PowerPoint presentations. Farmers learnt about markets by word of mouth or via calling one another. Moving forward, farmers had already come to a consensus that they needed to work with a common voice since this would enable them to set uniform prices for their produce and seek markets as a group. They mentioned that this was an opportunity where technology that fostered collaboration between farmers championing various interests and expertise could support them in achieving this goal.

DISCUSSION

The goal of our study was to understand routine practices and articulate how a group of farmers in an irrigation scheme used technology while farming. We focus on understanding when technology was used and the reasons for this usage. In this section we illustrate areas that designers will need to explore further when creating or deploying technologies that support farming in rural parts of Kenya.

A platform for Activity Awareness

Knowledge Sharing

Technology based information gathering among the farmers we studied generally fall into two main areas; providing an educational platform to different sets of farming populations, and focusing communication on coordination of activities towards a common goal.

Our results point to the fact that even though communication between farmers and agricultural officers was mainly around solving problems, there was value for the farmers to understand the practicality of the suggested solutions based on economic ability, comparison to alternative possible solutions available, and experience that the famers already possessed. Disparities between populations in terms of economic income has been reported as an indicator of digital divide when thinking about ICT interventions in rural communities of marginalized economies [8,9,38,22].

A broader understanding on how low income farmers went through the cycle of seeking information in tandem to its perceived value is key to providing design directions for exploration [34,35]. The practice of working together such as attending Barazas, or planting the same type of crop, provoke thinking about the relationship between ICTs and

collaboration and designing systems that can support achieving a common goal [20]. Participatory design provides an opportunity for the researcher and users to work together in the design development process. However, social relationships and cultural values play a huge part in constructing public events [10,37]. Therefore, as participatory approaches are applied, designers and researchers should analyse the relationship between social structures within communities and individual agencies because the process of social transformation and structural change to the system of social relations can lead to the reproduction of inequalities and exclusion of vulnerable people [10,37]. This calls for careful interaction with farmers to understand internal politics, local dynamics, and historical changes in the community that have led to the challenges currently being addressed. Understanding internal politics and using mixed methods ensures that solutions support the farmers in achieving goals shaped by what they perceive the project could offer.

Focus on Communication and Co-ordination of Activities

Our study results also highlight how farmers within the scheme formed sub groups to advance various goals that negated the overall aim of the irrigation scheme which was to increase food productivity in the irrigated community.

Farmers in other sub-Sahara countries have reportedly used phone features such as speakerphones to engage in group discussions with agricultural experts. Other studies point to the increasing use of mobile phones to access markets similar to our findings where farmers used their mobile phones to communicate with brokers similar to [30]. We also found that low income farmers engaged with brokers even though past records pointed to exploitation by such buyers. This creates a need for the design of collaborative technologies that pair collaboration between successful and low income farmers similar to [21,31]. Such collaborations can reduce the need for low income farmers to engage with external entities that aim to exploit them in rural settings of developing countries [10].

Even though our participants did not report the use of social media to exchange information regarding the conduction of their activities, the communication/coordination of activities is likely one opportunity for ICTs to make a difference. The idea of group networks [27,28,29], can guide the formation of symbiotic associations that tear across economic disparities, selective provision of farming knowledge or resources, with the aim of integrating participation to different stakeholders rooted in a relation of mutual trust. This can create room for sharing knowledge and increase access to information via technology for the set who are unwilling to work together with others, or form allegiances based on individual interests. Phone calls about unfair water rationing can now be directed to the balanced newly constituted associations based on solving existing issues rather than advancing inequalities. Discussions based on a dynamic relationship of mutual trust and respect should aim to counter manipulation by stakeholders for their own benefit to identify goals that address the needs of the newly formed farmer associations [10,16,35]. Trust should be continuously built by handing the farmers substantial influence in project implementation and decision making as this can lead to more positive outcomes since the community of farmers will feel appreciated and involved more.

We caution that our work is not in a place to provide full-on design guidelines at this point as this work is a matter of design process and exploration. To fully understand how one should design in this space and provide more concrete instantiations of design suggestions than what we currently do, one needs to actually start designing in an iterative fashion, which indeed is our own next step. Throughout this process, our results can steer design directions, anticipate social issues and challenges, and guide design in a manner that would cause technology to likely fit the farming community's cultural practices the best. Thus, we are presenting knowledge sharing, affirmation of good practices, access and distribution of water and coordination of market opportunities as a set of design areas that researchers should explore further. As well, we highlight social factors such as inequitable distribution of resources, access to conflicting farming information from separate sources (government officials versus traditional farming approaches), lack of cohesion in marketing approaches and a social or preferential divide among farmers as challenges that will affect design work in these spaces the most.

CONCLUSION

Our paper explores factors shaping how and why rural farmers in Kenya use technology while connecting their routine farming activities. We found that farmers generally relied on traditional farming practices and mainly used mobile phones to share information around learning about better farming practices and markets for their produce. The participants also indicated interest in technology solutions that could provide information on soil fertility, support equitable distribution of irrigation water and also connect farmers with potential buyers. Even though a considerable number of our participants were not technology savvy, our results point to ways through which collaborative technology such as mobile phone chat applications could be leveraged to promote information sharing in rural farming communities where persistent disparities in terms of income and access to financial support opportunities are prevalent. Ultimately, we hope this study will inspire future research into how collaborative technologies might be better designed and be more meaningfully situated within rural farming communities in developing countries.

ACKNOWLEDGMENTS

We acknowledge the contribution of our colleagues Kala Fleming and Elizabeth Ondula @ IBMRA for seamlessly organizing the study logistics and facilitating continuous

association with the participants. Timothy Nyota for reviewing and critiquing this work, and the Tharaka irrigation scheme team for supporting us via coordination of the site visits, participant selection and continuous welcome before, and even after the study period.

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