TECHNOLOGY FOR SMALL SCALE FARMERS IN TANZANIA: A DESIGN SCIENCE RESEARCH APPROACH

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ABSTRACT

Small scale farmers (SSF) in Tanzania are challenged by food insecurity, lack of infrastructure, lack of access to credit and services, and lack of reliable channels for farming information. Despite various initiatives the agriculture sector in Tanzania has remained poor. Unreliable information has been found as one factor that hinders decision-making and productivity. This study is the first step in a design science research (DSR) approach to address farmers' challenges directly with technology. This research studied the acute challenges, information channels, and information gaps of SSFs in Chamwino, Tanzania. Based on our previous qualitative results, a structured questionnaire containing 76 items on a Likert scale was administered to 150 small scale farmers in Chamwino, Tanzania. A response rate of 83% (*n*=124) was reached. The data was analyzed for descriptive statistics as well as basic measures of statistical association. The results show that farmers rely on tacit knowledge in regards of weather information, market data, plant and disease identification, and business management, and are vulnerable to middlemen frauds and inaccurate decision making. Many of these challenges can potentially be solved by technology. A number of engineering solutions for the basis of future DSR projects are proposed.

Keywords: agriculture, small scale farming, development informatics, developing countries, ICT4D, design science research

1. INTRODUCTION

In Tanzania, agriculture employs 75% of workers, contributes to 24.1% of GDP, 30% of export earnings, and 65% of raw materials for industries (URT 2013; Misaki et al., 2015; Barakabitze et al., 2015). A number of projects are active in developing the agricultural sector in Tanzania (see for example: Barakabitze et al., 2015). In recent years, the role of information technology in agriculture has attracted increased interest. Development informatics (DI) is an academic discipline that studies the role of technology in development (Heeks, 2014). In regards of the post-2015 development agenda (PTDA), and despite of several ongoing technology projects (see Misaki et al., 2015), technology for agriculture is currently an understudied area in the development informatics domain (Heeks, 2014). Moreover, development informatics is over-focused on social development and under-focused on economic development (Heeks, 2014).

ICT4D (Information and Communication Technologies for Development), which is closely related to development informatics, is often conducted by social scientists and focuses more on evaluating the feasibility of existing technologies rather than designing new ones (Sutinen & Tedre, 2010). We argue that ICT4D needs to integrate more with design science research (Hevner, 2007) in order to construct technological solutions that are adapted to the needs of developing regions. This is also well aligned with arguments from an information systems (IS) perspective, which calls for expansion of IS to new areas such as development research, with increased design science and action research approaches that construct new artifacts and study how well they work (Walsham, 2012).

Technology projects for agriculture vary a lot. They can, for example, target to improve agriculture research institutions (ARIs), extension officers, government officials, or various other initiatives and projects that are conducted in order to improve the agriculture sector. Technology projects can also directly target farmers and provide them, for example, with information about weather, crops, and market data (eg. Misaki et al., 2015).

This study takes a design science research (DSR) approach to study the information needs and decision making processes of a group of smallholder farmers in Chamwino, Tanzania. The leading idea is to build grounds for future DSR projects that directly address the challenges of smallholder farmers with the support of technology.

2. BACKGROUND AND RELATED STUDIES

2.1 Small Scale Farming

Over 75% of Tanzanians are employed in the agriculture sector (URT, 2013). Small scale farming (or smallholder farming) is typically characterized by the size of land ownership (less than 2-10 hectares (Chamberlin, 2008)). Small-scale farmers operate mostly in rural areas, and are the biggest group in the agriculture sector as a whole. Small-scale farmers are faced with crucial decision making all around their farming season, including: pre-harvest, preparation for farming, cultivation/tilling of land period, weeding period, after weeding period, harvesting period, and post-harvest. Despite an increase in the number of technology projects, the use of information technology among small scale farmers in Tanzania is still rare (Misaki et al., 2015).

In Tanzania, small scale farmers face a range of challenges such as food insecurity, lack of infrastructures, access to credit and services, information gaps, and changing climate conditions (Misaki et al., 2015; Barakabitze et al., 2015). In general, despite various initiatives, the agriculture sector has remained poor. Reasons for this include unproductive agriculture practices, low productivity of land, low production inputs, underdeveloped irrigation potential, limited access to capital and financial services, inadequate technological support services, infrastructure, lack of technical support, pests and diseases, erosion, environmental degradation, poor network of agricultural information services, accessibility and usage of agricultural knowledge and information among farmers (for various references, see: Barakabitze et al., 2015). Weak and unreliable information has been found to be one of the factors that hinder productivity (Barakabitze et al., 2015).

2.2 Decision Making and Information Channels

Success in farming relies on smart and timely decision-making. Smart decisions require reliable information, which is necessary in all phases of the farming season (see. Misaki et al., 2015). Information is required in production planning, adoption of beneficial cultivation processes, post-harvest management, marketing, buying inputs, and selling outputs (see Bertolini, 2004; Kalusopa, 2005; Poole & Lynch, 2003; Rao, 2007). A variety of sources for information are currently available for farmers. These include local organizations, input suppliers, rural agencies, extension officers, NGOs, radio and television broadcasts (Rao, 2007), and telecenters (Lwoga, 2014). In addition, farmers get information from local groups, relatives, and from their own experience. In Rungwe District, Tanzania, it was found that most farmers obtained market information from their relatives and traders, while 23% of farmers used information technology to obtain market information (Mwakaje, 2010). Thus, the sources and reliability of farming information may vary a lot.

The challenges with information can be categorized into several types. First, the *source of information* may vary a lot in regards of the *reliability of information* it can provide. In general, telecenters, extension officers or agricultural research institutions (ARIs) may be more reliable than traditional sources such as community elders, word-of-mouth, or superstitious beliefs. Second, the *dissemination and access* to information may constrain decision-making. For example, a study in Tanzania looked at telecentres, which repacked and distributed internet-based agriculture information to farmers via extension officers or directly, but the reach of the information for farmers was found to be small in scale (Lwoga, 2014). Third, the *skills and willingness to use* the information may vary. This category may include low literacy levels, the preference of traditional information sources over new ones. For example, in some cases farmers may prefer relatives, traditional information sources, and superstitious beliefs over more modern information channels (e.g., Misaki et al., 2015).

The *types of information* that farmers may benefit from may include, for example, improved access to market information, expert advice on farming, knowledge sharing of farming practices, information on pesticides, herbicides, storage, information on management, risk management, knowledge transfer, environmental impact, market access, and increased food traceability that leads to better food security in cases such as chicken flu (Gaiani, 2008). In addition, weather information is important for farmers (Misaki et al., 2015).

2.3 Technology Projects in Agriculture

A number of technology projects that target farmers in developing countries have been successfully implemented (e.g. Ali & Kumar, 2011; Kalusopa, 2005; Rao, 2007; Bertolini, 2004). In sub-Saharan Africa, the number of technology projects in agriculture is increasing, but is still low when compared to Asia and South America (Ajani, 2014). This may be due to the fact that policy and regulatory frameworks on telecommunications constrain infrastructure development, which is at the world's lowest level, and human capacities in the field of ICTs are still insufficient (Misaki et al., 2015).

In Tanzania, where the government has sought to include ICTs in the national development plans since 2003, about six projects – in the framework of GSMA Mobile for Development - are currently active in developing mobile services for the use of agriculture. The GSMA Mobile for Development[1] is a project that supports mobile phone based application development in various development domains such as mobile money, health services, women entrepreneurship, digital inclusion, green power, and agriculture. GSMA Mobile for Development brings together mobile operator members, the mobile industry and the development community to drive commercial mobile services for underserved people in emerging markets.

In Tanzania GSMA brings affordable GSM mobile connectivity to remote rural communities and areas previously unconnected, provides internet cafes in partnership with Vodacom using 3G HSPA technology that are managed by local entrepreneurs who charge a fee for the service. GSMA also promotes six projects listed in the mAgri deployment tracker[2]. The GSMA mAgri tracker maps the products and services that use mobile in agriculture across the developing world. The product offerings include market intelligence and information, peer-to-peer learning, data collection, delivery channel for information, and weather services.

Two of the GSMA mAgri tracker projects (Tigo Kilimo, Z-Kilimo) work on the unstructured supplementary service data (USSD)-platform and SMS-based technologies and are agricultural value added services (Agri VAS) offering farmers in Tanzania relevant, timely and actionable information via mobile phones across three domains: agronomic

[1] http://www.gsma.com/mobilefordevelopment/
[2] http://www.gsma.com/mobilefordevelopment/programmes/magri/tracker

practices on major crops, market price information, and weather forecasts. Content can be accessed via three mobile channels: Supplementary Service Data (USSD), Interactive Voice Response (IVR) and helpline. P4P project is a World Food Program initiative by the United Nations (UN) launched in 2008; it operates through Web, 3G network, and wireless networks (WIFI) in 20 pilot countries including Tanzania. The P4P project supports small scale farmers by providing the possibility to sell to a reliable buyer and receive a fair price for their crops. Geopoll is a global mobile survey platform that gives Africans access to farming data, including market prices and standards requirements.

In general, small scale farmers do not currently have access to smartphones, but they have simple phones that can access USSD services. In Tanzania, technologies do not probably yet reach a significant percentage of farmers (Misaki et al., 2015), and the connection between the usage of different services and farming success is not currently well studied. In addition, the farmers' perspectives towards using the current services are not well studied, and some farmers may be reluctant to use the services as they don't understand or trust the services well.

In addition to projects that directly target the farmers, other projects have targeted the information technology usage in agricultural research institutions (ARIs) (Barakabitze et al., 2015), telecentres (Lwoga, 2014), extension officers, and looked at how technology can improve extension services and communication between extension services and small scale farmers (e.g. Misaki et al., 2015).

2.4 Preliminary Results

This study is an extension to a previous study that we conducted in Chamwino, Tanzania (Misaki et al., 2015). That study was a qualitative study, which identified a number of crucial issues with potential future technology solutions. It was found that in the studied area, traditional prediction methods including behavior of insects were used. Information about sources of seeds and market information were unreliable, putting farmers vulnerable to middleman frauds. Also, reliable information about diseases, pesticides, and weak communication between extension officers were found to be among the pressing issues for farmers (Misaki et al., 2015). The design of this study was qualitative, and thus the study lacked generalizability over a larger population. Our previous study showed a number of challenges that the small scale farmers are facing, and identified a number of potential areas for future technology projects. These areas include weather forecasting, plant information, insect information, disease information, seed information, matchmaking, market data, bookkeeping, stock information, and business planning (Misaki et al., 2015).

3. Research Context

Chamwino is one of the seven districts of Dodoma region, which is one of Tanzania's 30 administrative regions. The population of Chamwino is approximately 330.000 (Misaki et al. 2015). Chamwino consists of 77 villages and 32 wards in five divisions: *Itiso, Makangwa, Mvumi, Chilonwa and Mpwayungu.* Chamwino is ethnically dominated by the Gogo group. Other ethnic groups in Chamwino include the Maasai, Barbaigs, Sandawe, Nguu, Rangi, and Mbuwi. Chamwino's land area is approximately 8000km^2, out of which 60% is potential land for agriculture (TPMO, 2012). The main economic activity for the people in Chamwino district are farming, livestock keeping and business activities like running small shops, selling of crops, selling of livestock, masonry, handcraft and working as security guards (TPMO, 2012). Small scale farmers in Chamwino experience low productivity on almost a stable basis, and most households' nutrition needs are not adequately met (TPMO, 2012). Chronic food insecurity is a pressing issue (Msaki et al., 2013).

4. Research Questions

The aim of this research was to explore the decision-making and information needs of small scale farmers in Chamwino district, Tanzania, in order to identify potential future technology interventions that would help farmers to make better farming decisions. This aim is approached through the following objectives: 1) *to identify the major challenges of small scale farming from the farmers' perspective,* 2) *to identify information gaining mechanisms and information gaps of farmers, and* 3) *to identify opportunities for future DSR projects.* The following research questions were set:

- RQ_1: *What are the acute challenges of SSFs in Chamwino?*
- RQ_2: *What are the information channels and information gaps of SSFs in Chamwino?*

This study is the first part of a design science research (DSR) project, which is motivated by a desire to directly improve an environment by building a technological artifact (Hevner, 2007). The first part in DSR is to identify and represent the opportunities and problems that have potential technology solutions in a given environment, and to provide technical requirements and evaluation criteria for future projects (e.g. what are the problems to be addressed by technology) (Hevner, 2007).

5. Methods and Data

The design of this research is quantitative. A structured questionnaire was generated from the themes identified in our previous qualitative study (Misaki et al., 2015), which used focused group discussions to collect information from small scale farmers. The themes were: *major farming challenges, climate and weather information, market information, plant and disease identification, business management,* and *information technology and future.* Survey questionnaire had 76 questions on a 7-point Likert scale (1=not at all true, 2=very little true, 3=slightly true, 4=moderately true, 5=quite true, 6=very true, and 7=completely true). Preliminary study on the questionnaire was conducted with test respondents to check and correct the completeness and consistency of the questions. The questionnaire was designed in English language but was translated from English to Swahili before data collection. All data was collected between July and September of 2015.

The respondents were coming from all the five divisions in Chamwino: *Itiso*, *Makangwa*, *Mvumi*, *Chilonwa* and *Mpwayungu*. In regards of sampling, in each of the divisions, two villages were randomly selected. In the selected villages, the ward and village executive officers (WEO & VEO) selected 10 to 17 suitable respondents from each village. The main selection criteria was a person's ability to read and write, who was household head, and who had been in farming business at least for several farming seasons. A total of 150 questionnaires were distributed to the respondents. A total of 124 questionnaire sheets that qualified for data analysis were returned. 26 questionnaire sheets were dropped because the response sheets were wrongly filled or damaged. Thus, the questionnaire received a 83% (*n*=124) response rate. The collected data was analyzed by using descriptive statistics and basic measures of statistical association in relevant parts. The results are presented as divided by the main themes introduced in the previous paragraph.

6. Results

The results of this study are presented below. The questionnaire items are shown in Tables 1,2,3 and 4, and explained in the sections below. In each of the tables, the questionnaire items are presented together with the total division of responses per each category. The modes (the value that appears the most in the data) are highlighted in the tables, and the average values are presented at the end of each row.

6.1 Demographics

This section presents the demographics of the sample. Most of the informants (66.9%, *n*=83) were male, while 33.1% (*n*=41) were female household heads. Most of the informants (85.5%, *n*=106) had completed primary school, while 12.9% (*n*=16) had completed secondary school, and two informants (1.6%) were diploma holders. The average total land owned by the informants was 15.46ac[3] (min=2ac, max=100ac), and average land cultivated was 9.17ac (min=2 ac, max=80ac). Average monthly income was 84475TZS [4] (min=30000TZS, max=225000TZS) and the average number of people in a household was 5.86 (min=2, max=12). 28 (22.6%) of the respondents were from the division of Itiso, 23 (18.5%) from Makangwa, 30 (24.2%) from Mvumi, 27 (21.8%) from Chilonwa, while 16 respondents (12.9%) were from Mpwayungu division.

	Not at all true	Very little true	Slightly true	Moderately true	Quite true	Very true	Completely true	*Avg.*
MAJOR FARMING CHALLENGES IN PREVIOUS FARMING SEASON								
1. Shortage of farming inputs	-	2	3	7	33	44	35	*5.77*
2. The transport infrastructure (road)	2	5	13	24	42	14	24	*5.18*
3. Access and quality of health centers	4	7	13	22	36	15	27	*4.87*
4. Access to credit from financial institutions	3	1	5	4	32	28	51	*5.81*
5. Interest rate of financial institutions	6	7	7	2	41	18	43	*5.35*
CLIMATE HAZARDS								
6. We experienced climate hazards (floods and/or drought)	2	4	4	12	42	23	37	*5.46*
7. Climate change made traditional weather prediction unreliable	4	3	15	3	44	28	27	*5.19*
8. Bad rainfall prediction caused loss in productivity	3	4	12	6	32	34	33	*5.37*
RAINFALL PREDICTION IN THE PREVIOUS SEASON WAS HELPED BY								
9. Advise from extension officers	61	30	7	3	10	4	9	*2.35*
10. Advise from the community leaders	13	20	18	10	35	13	15	*4.07*
11. Looking at behavior of insects	24	17	19	11	35	7	11	*3.65*
12. Occurrences of earthquake	33	21	17	14	20	12	7	*3.25*
13. Sprouting of tree leaves	7	13	4	5	48	22	25	*4.94*
14. Observing wind and windy rainfalls	13	13	7	15	43	16	17	*4.44*
15. Receiving information from television and/or radio	23	17	14	4	38	14	14	*3.93*
16. Internet	79	26	4	3	6	4	2	*1.80*
17. Application of mobile phones	72	34	4	2	5	4	3	*1.85*
18. The current weather prediction methods are accurate	38	21	19	20	17	3	6	*2.92*
19. It would be interesting to receive rainfall information through mobile phones	8	11	5	4	31	20	45	*5.25*

Table 1: Major Farming Challenges and Climate + Weather Information

There were differences among incomes between different regions. The following average monthly incomes per regions were found: Itiso (98000 TZS), Chilonwa (94000 TZS), Makangwa (83000 TZS), Mvumi (66000 TZS), and Mpwayungu (73000 TZS). The

[3] One "international acre" (ac) equals to 4046.8564224 square meters (m^2)
[4] 84475TZS equals roughly to 35€ (with exchange rate of 14th October 2015)

differences between earnings in the five different divisions were statistically significant (Kruskall-Wallis H-test $\chi^2(4) = 11.493$, p=.022). No statistically significant differences were found between the income level of informants per gender. There was no association as measured by Spearman's rank correlation coefficient (ρ) to be found between monthly income and total land owned, acres cultivated, or number of people in household.

The major crops produced by farmers were maize, sunflower, millet, sorghum, sesame, legumes and nuts. Other crops produced in some specific division and in low quantity were grapes, onions, tomatoes, sweet potatoes, cassava, bananas and vegetables.

6.2 Major Farming Challenges

The major challenges that the farmers' had experienced during their previous farming season were measured by five questions (see the first section in Table 1), that were derived from our previous qualitative study (Misaki et al., 2015). The results confirmed our previous qualitative results that all the measured issues (*shortage of farming inputs*, *transport infrastructure*, *access to health centers*, *access to credit*, and *interest rate of financial institutions*) are major challenges for the farmers. In addition to this, the results also show that the majority (90%) of farmers' families do not have access to electricity. This confirms the observation from previous studies that small scale farmers operate in a very challenging environment with inadequate farming equipment, weak transport infrastructure, limited access to health care, and no electricity. Weak access to credit is a pressing issue among farmers, which has been observed as a significant challenge in previous studies about small scale farming, as well as among other informal workers in developing countries (e.g. Mramba et al., 2015; 2016).

6.3 Climate and Weather Information

Section *climate hazards* in Table 1 shows the farmers' perceptions about the impact of climate hazards in their farming activities, and section *rainfall prediction* in Table 1 shows the main methods for rainfall prediction in the previous farming season. The results show that most of the farmers had experienced climate hazards in the form of floods or draught in the previous farming season (question q6), and that the farmers were of the perception that climate change had had a serious impact to the reliability of traditional weather prediction methods that the farmers use (q7).

In regards of rainfall prediction, which has been identified as a significant and pressing issue among farmers in previous studies (eg. Misaki et al., 2015), several issues were revealed. First, it was shown that the farmers perceive bad rainfall prediction as a major cause for loss in productivity (q8). Second, the results confirmed the current information channels for rainfall prediction. The results show that information received from extension officers, Internet or through mobile phones, were rare (q9, q16, q17). The results also showed that traditional methods such as advise from community leaders (q10), looking at behaviors of insects (q11), sprouting of tree leaves (q13) were common. Also, receiving weather information through television or radio was common (q15). Most of the farmers were of the opinion that their current weather prediction mechanisms are inaccurate (q18), and most of the farmers expressed their interest in receiving rainfall information through mobile phones in the future (q19).

6.4 Market Information

Our previous qualitative results (Misaki et al. 2015) show that farmers experienced various complications originating from middlemen who have authority of setting the prices, while the farmers do not have any means to access market information. Frauds were also found when deciding which seeds to buy, because some dealers were explained to be selling expired or watered seeds, which would call for reliable ways to detect the trustworthiness of products and prices, and to get rid of fraudulent dealers. The data from this study (see Market information section of Table 2) confirmed that *middlemen frauds* (q1) were a pressing issue for the farmers. The data also confirmed that reliable market information including prices of crops, and information about where to sell was missing (q2). Fraudulent seed dealing was also found to be a complicating factor (q3).

	Not at all true	Very little true	Slightly true	Moderately true	Quite true	Very true	Completely true	*Avg.*
MARKET INFORMATION								
1. Middlemen frauds caused a serious challenge	8	10	11	2	43	20	30	*4.95*
2. Reliable market information (price of crops, where to sell) was missing	3	4	7	4	43	31	32	*5.43*
3. Fraudulent seed dealers was a big problem	14	13	6	4	46	27	14	*4.55*
4. Information of quality seeds would have improved productivity	1	3	1	6	38	33	42	*5.77*
5. It was difficult to obtain certified seeds	2	4	5	6	46	31	30	*5.44*
6. I would be interesting to receive seed information through mobile phones	9	10	2	3	42	24	34	*5.15*
7. I would be willing to receive market information through mobile phones	5	5	1	3	41	32	37	*5.53*
8. I would be willing to receive transport cost information through mobile phones	2	3	1	2	37	31	48	*5.85*
IRRIGATION								
9. I practice irrigation farming system	65	34	5	5	9	2	4	*2.04*
10. Lack of water sources leads to poor and none practice of irrigation	16	10	5	20	36	19	18	*4.44*
11. Reliable information on irrigation techniques would improve crop production	-	10	2	3	48	29	32	*5.45*
12. I would be interested in participating in irrigation farming	1	1	-	4	37	31	50	*5.94*

Table 2: Market Information and Irrigation

The study informants were heavily of the opinion that information about quality seeds would improve their farming productivity (q4). The data also shows that for the farmers, it was difficult to reliably obtain certified seeds (q5). In regards of future technology, the results showed that the study informants were motivated towards future mobile technology solutions that would give increased access to seed information (q6), market information (q7), and transport information (q8).

6.5 Irrigation

The results (section Irrigation in Table 2) show that the informants considered the lack of proper irrigation (q9), and lack of water sources to be a serious challenge for farming (q10). The informants were also highly interested in future irrigation solutions (q11, q12). Irrigation is highly important for the improvement in farming activities, and future efforts need to look into the best ways to provide contextualized irrigation solutions. The role of technology in improving irrigation, providing education about irrigation, and delivering irrigation services and solutions to farmers needs to be inspected in the future.

6.6 Plant and Disease Identification

Various diseases, unwanted plants, insects, and dangerous animals have been shown to seriously complicate farmers' activities (Misaki et al., 2015). Protection against these is highly important, as dangerous animals such as orangutan, monkeys, birds, caterpillars, and diseases such as *ombelele* (white bacteria) cause low productivity. Protective actions against these include shouting, using pesticides, and praying (Misaki et al., 2015). Dealing with these challenges include making a number of decisions starting on which pesticide to use. The data from this study confirms that plant diseases are a serious problem for farmers (q1 in Table 3), and that detection of diseases (q2), detection of harmful insects in plants (q3), and choosing the right action to deal with diseases and insects (q4) are all pressing issues for small scale farmers. It was very common for farmers to have experienced plant destruction by animals such as monkeys (q5: *average 5.68*, *mode 7; completely true*).

	Not at all true	Very little true	Slightly true	Moderately true	Quite true	Very true	Completely true	*Avg.*
PLANT AND DISEASE IDENTIFICATION								
1. Plant diseases has been a serious problem	-	3	1	6	51	26	37	*5.67*
2. Detecting diseases has been a serious problem	1	4	5	5	33	39	37	*5.66*
3. Detecting harmful insects in plants has been a serious problem	1	5	6	7	39	28	38	*5.53*
4. Choosing the right action to deal with diseases and insects has been a serious problem	1	2	5	12	49	19	36	*5.48*
5. We experienced plant destruction by animals (monkeys etc.)	3	1	2	10	37	29	42	*5.68*
6. It would be interesting to receive information on soil testing and fertilizer use through mobile technologies	5	2	-	2	42	29	44	*5.72*
7. I would we willing to receive disease and insect information through mobile phones	3	-	2	3	44	28	44	*5.78*
BUSINESS MANAGEMENT								
8. We recorded business transactions (purchases and sales) in books	51	47	6	4	13	2	1	*2.12*
9. Typically farmers record their profits and losses	40	48	10	6	17	2	1	*2.37*
10. Many farmers had a book to record their business transactions	50	48	6	4	13	3	-	*2.12*
11. I know a farmer who records all business transactions	33	48	20	5	11	4	3	*2.49*
12. Targeted outputs and inputs were well planned	24	39	8	11	25	8	9	*3.27*
13. Not keeping records caused problems (running out of stock in middle of season)	4	6	2	2	34	49	27	*5.51*
14. Would you participate in training on business planning if available	4	1	-	1	46	16	56	*5.87*
15. Would you be interested in using mobile phones to keep business records	5	3	1	4	37	31	43	*5.66*

Table 3: Plant and Disease Identification and Business Management

Similar to the other sections, the data of this study confirmed the study informants' willingness and motivation towards receiving improved information in regards of soil testing and fertilizer use through mobile technologies (q6), as well as for receiving disease and insect information through mobile technologies (q7) in the future.

6.7 Business Management

The data from this section (business management section in Table 3) confirms that small scale farmers in Chamwino do not keep systematic records of business transactions such as purchases or sales (q8), or profits and losses (q9). Although there are some farmers who keep books (as seen from the division of responses in questions q8, q9, q10, q11), the general tendency is not to keep systematic records. Similar results in regards of lack of record keeping have been found in other studies that have targeted informal workers in developing countries (e.g. Mramba et al., 2016; Gomera & Apiola, 2015). Also, most of the farmers were of the opinion that targeted outputs and inputs are not systematically planned (q12). The study participants were heavily of the opinion that the lack of record keeping may result in problems such as running out of stock in the middle of the season (q13). Studies of other informal workers have found two main reasons for lack in records keeping: no skills, and no perceived benefits (Mramba et al., 2015).

Lack of education and skills in business seems to be a pressing issue among small scale farmers as well as other informal workers, and they are areas where technology might play a significant role in the future. The results of this study showed high motivation among the small scale farmers in receiving business planning education (q14), as well as testing mobile phone based applications to help in business planning (q15).

	Not at all true	Very little true	Slightly true	Moderately true	Quite true	Very true	Completely true	*Avg.*
About technology								
1. I have experience about information technology (computers and smartphones)	57	48	4	7	5	-	3	*1.93*
2. If available, I would participate in training about ICT	3	2	-	3	44	24	48	*5.80*
3. I use phone calls and SMS mainly for personal purposes	16	7	2	3	50	27	19	*4.78*
4. Phone calls and SMS are often used for farming related purposes	42	51	5	-	15	6	5	*2.46*
5. I sometimes use internet on my phone	48	49	4	3	15	2	3	*2.24*
6. I take photos with my phone	40	43	2	3	16	7	13	*2.88*
In the future								
7. I believe access to information and mobile services would improve our livelihood	3	4	3	47	22		45	*5.72*
8. Would you be interested in participating in a project of testing information services for mobile phones? Those services might include market data, weather, plant identification, and other types of farming information.	2	3	4	1	48	24	42	*5.66*

Table 4: ICT Usage and Patterns

6.8 Information Technology and Future

The data confirmed that 74% of the study participants had access to mobile phones, and 78% had access to a radio receiver. However, other technologies were found to be much more rare as only 3% of study participants had access to computers, 6% had access to internet (through mobile phone or computer), 9% had access to television, and none of study participants had access to global positioning system (GPS).

In regards of current technology and mobile phone usage patterns, Table 4 shows the responses of the informants of this study. Most of the respondents had very limited experience about information technology, including computers and smartphones (q1). However, there were some participants who had experience. It is interesting to note that a high number of participants reported interest in receiving training about information and communication technologies (q2).

In regards of current mobile phone usage patterns, most of the informants reported that phone calls and short messages (SMS) are used mainly for personal purposes (q3). However, as can be seen from Table 4, there were some informants who reported to use phones for other purposes also. Answers to question q4 shows that most informants did not use phone calls or short messages for farming related purposes. Most of the informants did not use phones for Internet or taking photos (q5, q6). However, Internet use and taking photos was not completely foreign, as some respondents reported to do those activities also.

The study respondents had moderately high belief in the potential of future information technology solutions to improve their livelihood (q7), and high interest in participating in future technology projects that would test the impact of various technology services such as improved market data, weather data, plant identification, or any other types of farming information that would be of benefit for the farming activities.

7. DISCUSSION

Research question RQ_1 asked "*What are the acute challenges of SSFs in Chamwino?*" This study strengthened our previous understanding about the challenges small scale farmers face in Chamwino (Misaki et al., 2015). The acute challenges of farmers are poverty and lack of resources. The farmers work under very challenging conditions with poor nutrition and inexistent health care, and with poor farming inputs. The farmers lack the means, capital, information, and ways to improve their living conditions in order to rise out of poverty. They are also in a weak position in the agricultural production chain, and are vulnerable to various kinds of middlemen frauds because of isolation from reliable market data. This study has confirmed that the list of acute challenges include: *shortage of farming inputs, transport infrastructure, access to healthcare and health centres.* The most pressing issue that restricts farmers' business found in this study was *limited access to credit.*

Other important issues identified by this study were *changing climate patterns*, which complicate traditional prediction, and *unreliable weather prediction methods.* For example, traditional methods were guiding decision-making and information was not well received from authorities such as extension officers. Other acute challenges included *lack in irrigation,* and *lack in irrigation knowledge, challenges in plant and disease identification,* and *lack of basics in business planning and management.* The lack in business skills has been identified as a challenge also among other informal workers (Mramba et al., 2016; Gomera & Apiola, 2015), and calls for increased educational efforts in the future. In general, it has been argued that development informatics is over-focused on social development and under-focused on economic development (Heeks, 2014).

Research question RQ_2 asked "*What are the information channels and information gaps of SSFs in Chamwino?*" The results of this study showed that several information gaps restrict the effective decision-making and daily business of small scale farmers. First, *access to health information* was found to be a challenge. Second, *traditional weather information channels* were found to be widely used. These included advise from community leaders, and looking at behaviors of insects, and tree leaves. In regards of more modern information channels, radio was found to be used, but Internet and mobile phones were not used as information channels. Moreover, communication with extension officers was found to be very constrained. Thus, improving weather information channels and extension officer communication are in high priority among the future challenges for development and DSR projects in Chamwino.

Third, *lack of market information* has put farmers in a position where they are vulnerable to different types of middlemen frauds. They lack access to market information, and certified seed data. Fourth, *plant and disease information* was found to be lacking, and farmers business was constrained by diseases and insects and lack of means to detect and deal with these. Fifth, *business management information* was found to be inexistent. This contains basic information that is beneficial in running a business including cash inputs and outputs, and spending. Our previous study found that weak business planning sometimes resulted in going out of stock for domestic consumption, which caused malnutrition (Misaki et al., 2015). Information technology might provide means for better planning, record keeping, and managing an agricultural business.

In all areas, this study has shown that farmers have high interest and willingness to participate in future technology projects that test improved means for information delivery.

7.1 Proposed DSR Projects and Future Research Directions

This study has demonstrated high potential for future design science research (DSR) projects in the area of small scale farming in developing countries in general and particularly in Tanzania. Of course we are not the first to discover this as can be seen from the rapidly increasing efforts and projects of technology implementation for farmers (see Section 2.3). However, while the number of projects are increasing, many of the projects are still in their infancies, the services are still in the prototyping and testing phase, the services are not reachable to the majority of farmers, and the impact of using services to farming success is not well proven. Also, it needs to be kept in mind that technology alone can't solve the problems of small scale farmers. However, technology can play an important part in development efforts that are conducted together with other economic, developmental, governmental, and research oriented projects and efforts. Of the numerous challenges that small scale farmers are facing, increased information accuracy and availability is a promising avenue for future studies. That is the area where this project is also working on.

A number of DSR projects can be proposed for the future. These can be divided roughly into two categories. First, design science research is needed to test various applications that improve the information accuracy and accessibility of farmers. This can include improved communication between farmers and extension officers, improved information flow from agricultural research institutions to farmers, improved access to global weather data, and improved access to market information. Mobile phone based agro services can include disease and unwanted plants databases, camera-based detection of plants and diseases, advisory services for increased communication. Second, learning services of the future might include various applications that provide training to farmers. This might include, for example, training on improved business skills, business planning, and record keeping. Also, in addition to targeting directly the small scale farmers, it is important to target all the other initiatives, agencies, and organizations that work for the benefit of the agriculture sector with design science research efforts.

In regards of DSR, an initial step is to understand the current technological solutions well (Hevner, 2007). Thus, it is important to see how well the current solutions address the information gaps of farmers in different areas. For example, it is important to look if the information that the current services provide is accurate, usable, and useful for the farmers, and if the farmers are willing to use that information. In addition, it is important to understand what is the reach of the current projects and services, what are the business models of the services, and what set of different information needs the current solutions are addressing. In regards of those information needs that the current products cover, it is important to understand how well they cover the needs. This is an important step that needs to be taken into consideration in order to understand the current information needs and the technological gaps with the current solutions. In other words; it is important to avoid reinventing the wheel.

Information technology graduate programs are being initiated in universities of developing countries at an increasing pace (e.g. Apiola & Tedre, 2012). It is of fundamental importance that DSR projects like the one introduced in this study are included in the curricula of technology programs. This is because technology universities must focus on teaching technology students how to specifically work on African problems. It is known that one challenge in technology education is that the curriculum and pedagogical models are too often directly imported from the Western world. Locally developed and implemented ICT projects will help Africa to avoid remaining as a passive recipient of technologies that are developed by overseas corporations, and help to increase contextually relevant science, technology, and innovation (STI) capacities.

In addition to DSR projects, a number of future research directions can be identified. While this study has covered a number of issues ranging from weather forecasting to business management and market data, our research has touched upon those issues only quite superficially. In-depth studies on market price information, rainfall prediction, middlemen frauds, or records keeping behaviors are required. For example, one important research track for the future would involve a better understanding of both the chain and network of actors involved in agriculture business per different farming products and of the mechanisms that restrict the empowerment and entrepreneurship of small scale farmers. It is clear that small scale farmers are a crucial link in this global chain. However, their position is one of the weakest as they suffer from low productivity, malnutrition, and poverty, among other things.

7.2 Future Work

This research about mobile technologies and agriculture is conducted as a part of a business informatics research group that is operating in collaboration between College of Business Education (CBE), Dar es Salaam, Tanzania, and the University of Eastern Finland (UEF), School of Computing (Apiola et al., 2015). This research group is working on a series of cases where informal workers are targeted with DSR research in order to directly address their daily challenges with technological solutions. The other domains of work in addition to small scale farming include street traders, business incubators, micro businesses, and microfinance institutions. Our research group includes a mobile lab, where mobile applications are being developed for research purposes. The mobile development activities are conducted in collaboration between software engineering students from Finland and Tanzania, researchers of our research group, and informal workers.

8. Conclusions

It is a well known fact that developing countries need to improve their science, technology, and innovation (STI) capacities, and increase research and development (R&D) activities that directly contribute to economic and human development (e.g. Trojer, 2014). Small businesses need to be empowered. Technology can play a significant contribution to this, if implemented well. The production of ICT-based knowledge and products can contribute directly to wealth creation and the use of ICTs can contribute indirectly to national development through its impact in social and economic sectors such as agriculture, health and education.

This requires, among other things, increased amount of DSR research, and the expansion of ICT4D from only evaluating technologies into constructing new technologies. These activities need to be increasingly brought into technology hubs, and technology programs in universities. However, it must be kept in mind that technology initiatives are not sufficient alone, but must be brought to work in collaboration with other legal, environmental, political, and economical efforts to improve the business prospects of small scale farmers and other informal workers. This study has shown a number of challenge factors of small scale farmers in Chamwino, Tanzania, and provided a number of potential practical ideas for future DSR projects.

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