# Exploring farmers' intentions to adopt mobile Short Message Service (SMS) for citizen science in agriculture

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## Abstract

Understanding farmers' intentions to use new technologies for agricultural data collection is essential in developing digital citizen science in agriculture. While more advanced technologies are available, to reach smallholder farmers simple technologies such as mobile SMS are needed. The main objective of this study was to explore the acceptance of mobile SMS technology by smallholder farmers to provide farm related information. A second objective was to assess the role of farmer's characteristics (i.e., age and experience) in predicting farmers' intentions to adopt mobile SMS. This study extended the unified theory of acceptance and use of technology (UTAUT2) model with constructs from trust, personal innovativeness in information technology and mastery-approach goals. The sample (N = 220) consisted of a group of smallholder farmers from three Ethiopian regions involved in a mobile SMS experiment and a control group. Structural equation modelling showed that intentions to adopt mobile SMS technology for agricultural data provision were predicted by the perceived usefulness of the technology (performance expectancy), the effort needed to use the technology (effort expectancy), the cost of using the technology (price value) and the trustworthiness of the organising body (trust; e.g., organisations behind the citizen science initiative). Multi-group analysis using farmer's age and experience as moderator variables further revealed that performance expectancy was important for younger farmers, whereas price value was important for farmers who did not participate in a mobile SMS experiment. This study generates useful information and implications for citizen science practitioners, policy makers and mobile application developers by identifying the driving factors for farmers to adopt mobile SMS for agricultural data collection.



***Keywords:*** Mobile phone, citizen science, data collection, unified theory of acceptance and use of technology, smallholder farmers

## 1. Introduction

Closing the yield gap between actual and potential yields is a key strategy for increasing crop production on existing cropland (van Ittersum et al. 2013). To conduct farm-level yield gap analysis, detailed information about soil, management activities, farm(er) characteristics and socio-economic factors for a large number of farmers is needed (Beza et al. 2017). However, costs and time limit feasibility of collecting this information. Citizen science, the involvement of citizens such as farmers, in the research process (Dehnen-Schmutz et al. 2016), supported by the proliferation of mobile communication technologies such as smartphones allows for collecting a large amount of data (Herrick et al. 2013). Although the use of citizen science in agriculture is in its early stage, recent studies showed the potential of citizen science in agriculture (Minet et al. 2017; Rahman et al. 2015; Rossiter et al. 2015; van Etten 2011). Recent reports on the next generation of agricultural system data, models and knowledge products also emphasized potentials of innovative data collection approaches (Antle et al. 2016; Janssen et al. 2016).

According to Nov et al. (2011), volunteer's participation in digital citizen science is grounded on two facilitating pillars. The first is motivational: how to attract and retain people who would be willing to contribute to citizen science initiatives. Recruiting and sustaining community members to participate in citizen science requires an understanding of the motivations of the community to participate. Beza et al. (2017) showed that while fun has appeared to be an important factor to participate in other citizen science projects, this was not the case for smallholder farmers in Ethiopia, India and Honduras. Two groups could be distinguished, one motivated by sharing information, helping and contributing to science, and one motivated by expectation, expert and community interaction. The second pillar - which the current study investigates - is the technological pillar: developing systems to collect, manage, and aggregate large amount of data. The rapid spread of mobile phones, especially in developing countries, creates the opportunity to use mobile phones to support rural development (Qiang et al. 2011).

According to the International Telecommunication Union (ITU), seven billion people (95% of the global population) live in an area that is covered by a mobile-cellular network (ITU 2016). Considering its broad coverage, the utilization of mobile Short Message Service (SMS) for agricultural data collection offers a platform for agricultural citizen science projects. While more advanced technologies are available, including tablets, smartphones and remote sensing, to reach smallholder farmers simple technologies such as mobile SMS technology are needed. However, development of mobile networks alone does not guarantee use of mobile phones in yield gap information collection by farmers. It is thus necessary to explore the intention of farmers to adopt mobile SMS for agricultural data collection. Newman et al. (2012) discussed the importance of assessing technology adoption in future citizen science projects and openness to new technologies as they emerge. Although some studies exist on the adoption of mobile services (e.g. mobile government) in rural regions (Liu et al. 2014), to our best knowledge currently no studies exist on the adoption of mobile SMS for agricultural citizen science. The current study seeks to fill this gap.

The objectives of the current study are twofold. First, to explore the acceptance of mobile SMS technology by smallholder farmers for farm-related information provision, by identifying the factors that predict willingness to use mobile SMS technology for agricultural data provision. Second, to assess the role of farmer's characteristics (i.e., age and experience) in predicting farmer's intention to adopt mobile SMS.

## 2. Theoretical background

### 2.1. Adoption and use of information technology models

In this section, we provide an overview of the most commonly used theories in the context of adoption and use of mobile technology in order to build a foundation for our research model.

#### 2.1.1. Unified theory of acceptance and use of technology (UTAUT)

The unified theory of acceptance and use of technology (UTAUT; Venkatesh et al. (2003) was developed after a comprehensive examination of eight prominent user adoption models that earlier research had employed to explain information systems usage behaviour, namely: Theory of reasoned action (TRA), Technology acceptance model (TAM), the motivational model (MM), theory of planned behaviour (TPB), the PC utilization model, Combined TAM and TPB (C-TAM-TBP), innovation diffusion theory and social cognitive theory. The UTAUT postulates that behavioural intentions and behaviour are determined by four key constructs: (i) performance expectancy, (ii) effort expectancy, (iii) social influence, and (iv) facilitating conditions. The UTAUT model has been applied to examine a wide range of technologies (Ovčjak et al. 2015; Williams et al. 2015; Williams et al. 2011) in single and multiple countries (Im et al. 2011). Amongst others, the model has been used in studies examining the acceptance of mobile wallet (Shin 2009), mobile health (m-health) (Dwivedi et al. 2016), mobile learning (m-learning) (Sabah 2016) and mobile banking (Oliveira et al. 2014).

UTAUT was later extended into the UTAUT2 (Venkatesh et al. (2012) by adding three more constructs: (v) hedonic motivation, (vi) price value and (vii) habit. The UTAUT2 model thus comprises seven constructs (Figure 1. Individual differences- namely age, gender and experience - are hypothesized to moderate the effects of the aforementioned constructs on behavioural intention and technology use (Venkatesh et al. 2012). The UTAUT2 has received strong empirical validation in a variety of disciplines and task environments (e.g. Dwivedi et al. 2016; Baptista and Oliveira 2015) and serves as the theoretical basis for the present research.

The conceptual model used in the current research (Figure 1) extended the UTAUT2 model with additional antecedents from the concept of diffusion of innovation (i.e., personal innovativeness in information technology (PIIT)), trust (i.e., benevolence), and goal orientation (i.e., mastery-approach goals).

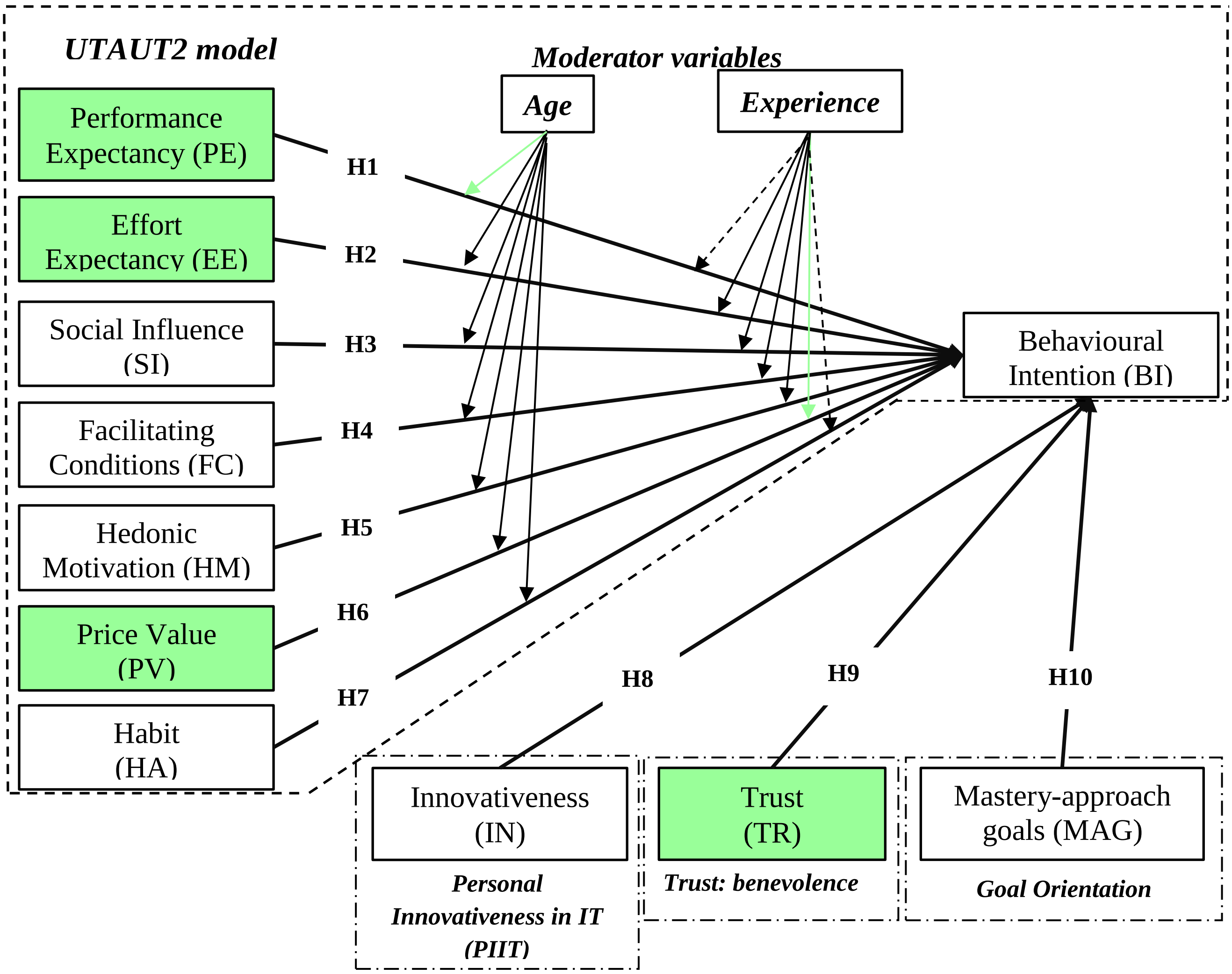


**Figure 1**: Conceptual model for the current research. The dashed line depicts a moderation effect of experience on performance expectancy and price value which was not in the original UTAUT2 model. Coloured boxes and arrows refer to constructs (section 6.3) and moderator variables (section 6.4) that were found to be significant.

### 2.1.2 Diffusion of innovation

Diffusion of Innovation theory (DOI; (Rogers 2002, 1995) views innovation diffusion as a particular type of communication process in which the message about a new idea is passed from one member to another in a social system. Importantly, and relevant for the conceptual framework we put forward, DOI suggest that one particular individual characteristic is important in the adoption of innovation: personal innovativeness (Yi et al. 2006; Agarwal and Prasad 1998). Agarwal and Prasad (1998) adapted the concept to the domain of Information Technology (IT) and proposed a new instrument to measure personal innovativeness in IT (PIIT) defined as, "*the willingness of an individual to try out any new IT"*. Since farmers participating in the current research did not have experience in using the SMS feature of the mobile phone for agricultural data provision, it is considered as a new technology for the farmers to test. Therefore, we included the PIIT construct in our conceptual model (Figure 1).

### 2.1.3 Trust

Secondly, we added trust to our model, defined as "*a willingness to be vulnerable to the actions of another party*" (Mayer et al. (1995). We seek to investigate how one of the key components of trust, benevolence, affects the acceptance of mobile SMS for agricultural data collection. Benevolence is the extent to which a trustee (i.e., to-be-trusted; e.g. researcher) is believed to want to do good to the trustor (i.e., trusting party; e.g. farmer) apart from an egocentric motive. If a farmer believes a researcher cares about the farmer's interests, the researcher will be seen as having benevolence for the farmer (Mayer et al. (1995).

### 2.1.4 Mastery-approach goals

According to goal orientation theory, one of the main goal types people can hold while performing a task is mastery goals (Nicholls 1984). The aim of people with a mastery goal orientation while approaching a task is to understand something new or to improve their level of competence (Yi and Hwang 2003). People with a mastery goal orientation consider ability as an incremental skill that can be continually improved by acquiring knowledge and perfecting competencies (Wood and Bandura 1989). Previous technology adoption studies have shown that mastery goal orientation has a significant positive effect on self-efficacy, implying that individuals with a mastery goal orientation are more likely to develop a higher sense of confidence (Yi and Hwang 2003; Hwang and Yi 2002). Janssen and Van Yperen (2004) revealed a positive relationship between mastery goal and innovative behaviour of employees.

## 3. Research model and hypotheses

In this section, we will detail our hypotheses pertaining the relationships between the proposed drivers for adoption and behavioural intention (BI) to use mobile SMS for agricultural data collection on smallholder farms specifically (Figure 1).

### 3.1. UTAUT2 constructs

"*Performance expectancy*" is the degree to which using a technology will provide benefits to users in performing certain activities (Venkatesh et al. 2012). In our research context, it is the degree to which a farmer believes that providing agronomic information to others (e.g. to agronomic experts) using mobile SMS will benefit the farmer. It indicates that individuals will use computing technology if they believe it will have positive outcomes in their day to day life (Compeau and Higgins 1995). In the original model of UTAUT, Venkatesh et al. (2003) found performance expectancy to be the strongest predictor of intention and the effect of performance expectancy on behavioural intention has been supported in the adoption of mobile services such as mobile banking (Baptista and Oliveira 2015), mobile cloud services (Park and Kim 2014), mobile maps (Park and Ohm 2014) and mobile learning (Ho et al. 2010). The reason for this is due to the benefits the technologies provide such as mobility, personalization, flexibility and convenience (Gilbert and Han 2005). One of the attractive features of mobile SMS for farmers to provide agricultural information is the ability to provide the information anywhere, at any time, without wasting much of their productive time to answer long surveys. As mobile SMS offers a convenient method for data provision, with no spatial constraints via a mobile device that has become ubiquitous, it offers practical benefits that are likely to be important drivers of adoption. Therefore, we hypothesised that:

> **H1:** Performance expectancy (PE) positively affects behavioural intention (BI) to use mobile SMS.

**"***Effort expectancy***"** is the degree of ease associated with farmers' use of technology (Venkatesh et al. 2012). In the case of mobile SMS data collection, some farmers might be more mobile SMS literate than others and, consequently, would expect to have fewer problems to use their mobile phone to provide agronomic information via SMS. If farmers find data provision using mobile SMS easy to use, then we expect them to be more willing to use it to provide agronomic information. Therefore, we hypothesised that:

> **H2:** Effort expectancy (EF) positively affects behavioural intention (BI) to use mobile SMS

"*Social influence*" is the extent to which farmers perceive that important others believe they should use a particular technology (Venkatesh et al. 2012). The underlying assumption is that individuals tend to consult their social network, especially friends and family, about new technologies and can be influenced by perceived social pressure of important others. Therefore, we hypothesised that:

> **H3:** Social influence (SI) positively affects behavioural intention (BI) to use mobile SMS.

"*Facilitating conditions*" refers to how farmers believe that technical infrastructure exists to help them to use the system whenever necessary (Venkatesh et al. 2012). Sending SMS requires some skills, such as being able to operate a mobile phone or tablet, inserting the receivers' mobile number, and writing/inserting the content of the SMS. A farmer who has educated household members or has access to a favourable set of facilitating conditions, such as support from extension workers, will have a greater intention to use. Therefore, we hypothesised that:

> **H4:** Facilitating conditions (FC) positively affect behavioural intention (BI) to use mobile SMS.

"*Hedonic motivation*" is defined as the fun or pleasure derived from using a technology (e.g. mobile SMS) (Venkatesh et al. 2012), and it has been shown to play an important role in determining technology acceptance and use (Brown and Venkatesh 2005). The greater entertainment value the mobile SMS brings, the greater acceptance intention farmers will show to use the mobile SMS. Therefore, we hypothesised that:

> **H5:** Hedonic motivation (HM) positively affects behavioural intention (BI) to use mobile SMS.

"*Price value*" is the farmers' cognitive trade-off between the perceived benefits of using mobile SMS and the monetary cost of using it (Venkatesh et al. 2012). It includes factors such as data service carrier costs, device cost and service costs. The price value is positive when the benefits of using the mobile SMS are perceived to be greater than the associated monetary cost. Therefore, we hypothesise that:

> **H6:** Price value (PV) positively affects behavioural intention (BI) to use mobile SMS.

"*Habit*" reflects the multiple results of previous experiences (Venkatesh et al. 2012) and people often consult their past behaviours as anchoring points to inform their future actions (Ajzen 2002). Therefore, we hypothesise that:

**H7:** Habit (HA) positively affects behavioural intention (BI) to use mobile SMS.

### 3.2. Additional constructs

In general innovation diffusion research, it has long been recognized that highly innovative individuals are active information seekers about new ideas. They are able to cope with high levels of uncertainty and develop more positive intentions toward acceptance (Rogers 1995). Therefore, we hypothesise that:

**H8:** Personal innovativeness in information technology (IN) positively affects behavioural intention (BI) to use mobile SMS.

The majority of the smallholder farmers' livelihood is dependent on agriculture and the probability of sharing their agronomic information using mobile SMS is highly dependent on the trustworthiness of the party (i.e., trustee) on the other side of the communication channel (e.g., agronomic experts, researchers, and research institutes). Farmers try to avoid using any technology which might bring any uncertainties and risks into their farming activity, such as disclosing confidential agro-business information to an untrusted recipient. Therefore, we hypothesise that:

**H9:** Trust (TR) positively affects behavioural intention (BI) to use mobile SMS.

The majority of the smallholder farmers' livelihood is dependent on farming. Therefore we believe that farmers will always look for options that help them to improve their agricultural production. To achieve this, farmers will strive for more skills and knowledge that help them to achieve their goals. Thus, in the context of adopting a new technology, farmers with a mastery goal orientation are expected to use the mobile SMS to acquire new skills and knowledge. Therefore, we hypothesise that:

> **H10:** Mastery-approach goal orientation positively affects behavioural intention (BI) to use mobile SMS.

### 3.3. Moderator effects

We hypothesise that age and experience moderate the effects of UTAUT2 constructs (PE, EE, SI, FC, HM, PV and HA) on behavioural intention (Venkatesh et al. 2012; Venkatesh et al. 2003). In our case, farmers who participated in the mobile SMS experiment are "experienced" and farmers who did not participate are "non-experienced". The effect of effort expectancy (EE), facilitating conditions (FC) and price value (PV) on behavioural intention (BI) are expected to be stronger for older farmers with no experience. The effect of performance expectancy (PE) and hedonic motivation (HM) are expected to be stronger for younger farmers with no experience. Lastly, the effect of social influence (SI) and habit (HA) are expected to be stronger for older and experienced farmers. The added constructs (IN, TR, MAG) could also be influenced by age and experience, but were not included in the analysis as further explained later.

## 4. Research context

### 4.1. Description of the mobile Short Message Service (SMS) experiment

During the 2014 and 2015 growing seasons, around 125 farmers from three regions in Ethiopia participated in an experiment where farmers sent their daily agricultural activities over the growing season by SMS. The experiment was conducted as part of two large ongoing projects, N2Afric (http://www.n2africa.org/) and Sesame Business Network (SBN; http://sbnethiopia.org/). Farmers in N2Africa have been participating in agronomic experiments and have been testing the effect of inoculants (I) and phosphorus (P) on the yield of legume crops (chickpea in our study area). Farmers in the SBN project have been testing the effect of applying the so called “20 steps” (production/agricultural practices identified & recommended by experts) in experimental plots in their own fields on sesame yields. The farmers that participated in the SMS experiments were randomly selected from the list of farmers participating in the two projects. However, one of the requirements to be part of the SMS experiment was that farmers needed to have at least a basic mobile phone in the household. In both years, farmers received a short training before the start of the growing season on how to send SMS messages. Short codes associated with the different agricultural activities (e.g. send “**1**” for sowing date, “**2**” for emergence) were introduced and farmers received a laminated A4 paper with the list of factors with the associated codes of the activities in their local language for later reference. The list of the factors that needed to be collected were identified from previous yield gap analyses (Beza et al. 2017). The main objective of collecting factors was to demonstrate the potential of innovative bottom-up data collection approaches (e.g. crowdsourcing) and use the collected factors in crop yield gap analysis studies that aim to identify the main causes of the crop yield gap at the farm level.

### 4.2. Data collection technologies used in the experiment

In order to receive and manage SMS messages sent by the farmers, FrontlineSMS desktop (http://www.frontlinesms.com/) and Ushahidi applications (https://www.ushahidi.com/) were used. We selected FrontlineSMS and Ushahidi as the messaging platforms because they are free and open source software tools and commonly used for data collection. FrontlineSMS enables users to send, receive and manage large numbers of incoming and outgoing SMS messages (Mahmud et al. 2010). FrontlineSMS does not require the internet to work, but does need to be connected to a mobile network. When a computer running FrontlineSMS is connected to a GSM (Global System for Mobile communication) modem or mobile phone, it is converted to a two-way text-messaging hub (Figure 2) (Mahmud et al. 2010). Farmers with mobile phones can send and receive messages to and from the platform, which is linked to a specific phone number with a SIM (Subscriber Identity Module) card. The software manages contacts, allows for mass-messaging, auto-forwarding and auto-reply.

Ushahidi is a platform for collecting, visualising and mapping information. Using FrontlineSMS and Ushahidi tools together can produce good results, with FrontlineSMS being used as a tool which can manage incoming SMS data which can then be visually represented using Ushahidi (Banks and Hersman 2009). The cloud-based version of Ushahidi (Crowdmap) was used in this pilot study to receive an automatically forwarded SMS message from the FrontlineSMS application. FrontlineSMS application uses a local SIM card; data sent to the application can only be accessed by people who have access to the local computer where the FrontlineSMS application is installed. To overcome this limitation, we linked the FrontlineSMS application with the Crowdmap platform so that SMS data received by FrontlineSMS is automatically forwarded to the Crowdmap platform and project partners (researchers) far from the implementation area and having connection to internet can also access the SMS data received using the Ushahidi Crowdmap platform.

We deployed the data collection platform at the International Livestock Research Institute (ILRI) Addis Ababa campus, where the Ethiopian office of N2Africa is located, and in the regional offices in Gondar and Humera, Ethiopia, for the data collection campaign for the Sesame Business Network project (Figure 2). Agronomists working for both projects received training before they were managing the FrontlineSMS application.

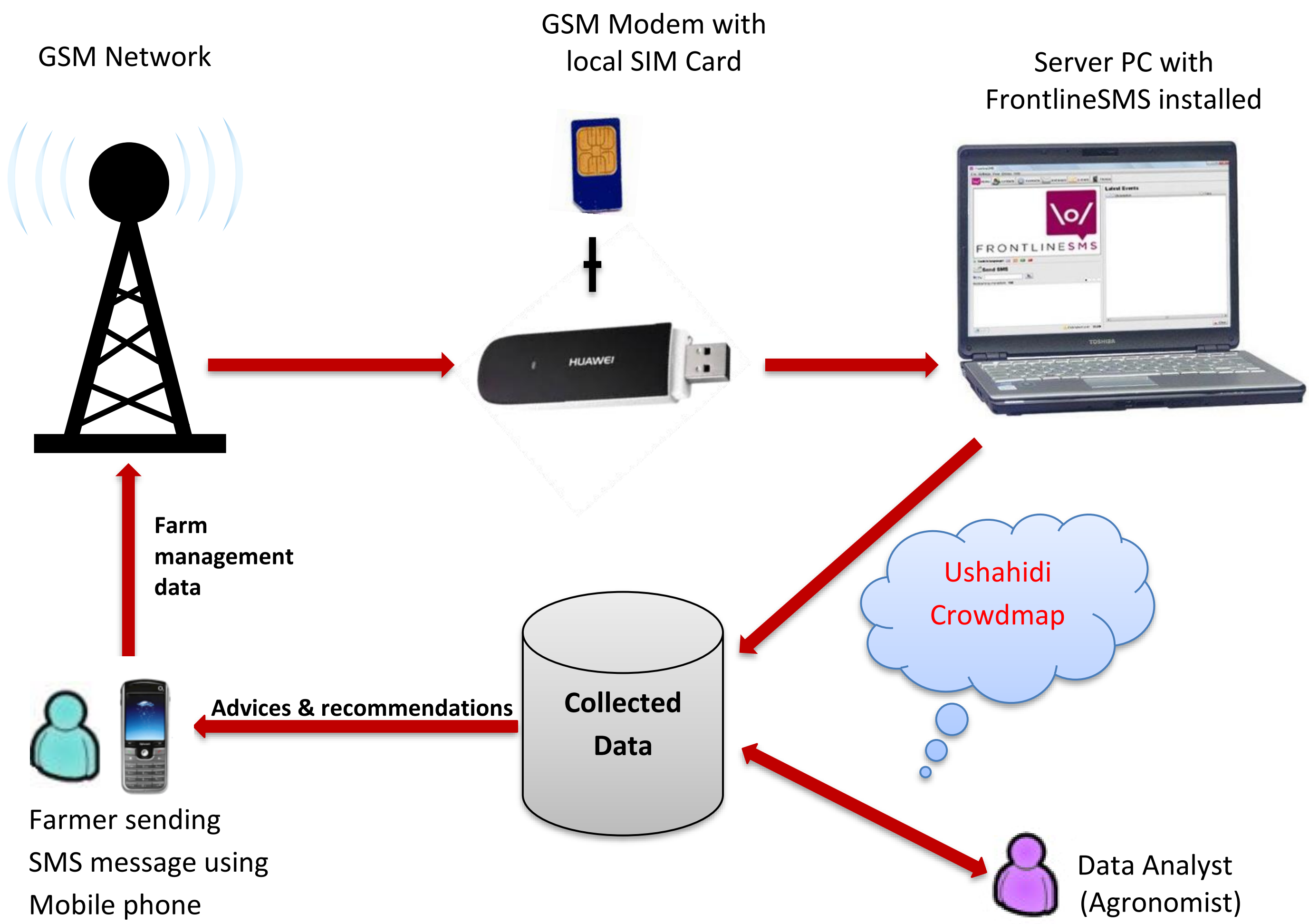


**Figure 2:** Overview of the information flow between the farmer and agronomists within the N2Africa and Sesame Business Network projects

During the 2015 growing season around 685 SMS messages were received from the farmers (Figure 3). As shown in the top right figure (Figure 3), using the Ushahidi Crowdmap application allowed for sorting the SMS messages based on their categories. In addition to its potential to collect detailed information from a large number of farmers, the application can also be used to visualise where there is an outbreak of pest or disease for immediate remedial actions. An overview of the individual factors belonging to each of the groups in Figure 3 is provided in Appendix 1.


**Figure 3:** Screenshots of FrontlineSMS (top left) and Ushahidi Crowdmap (top right) applications. The bottom figure presents the types of factors and frequency of SMS data collected from sesame fields during the 2015 growing season in North West Ethiopia.

## 5. Research methodology

### 5.1. Measurement tool

A survey was carried out in November and December 2015 using a standardised questionnaire. The questionnaire was originally written in English and a back translation process was applied (Brislin 1986) for the Ethiopian Amharic version and minor corrections have been done for the items that did not match precisely. The questionnaire consisted of two distinct sections. The first covered general information and demographic characteristics of the farmers. It also included questions on the use of SMS in the context of agronomic data collection for the specific projects. The second section covered the factors represented in our conceptual model (Figure 1). To make the objective of the second section of the questionnaire clear for the farmers, we used a "scripted introduction" which clearly describes that the follow-up questions were related to the use of their mobile SMS for agricultural data collection/provision. The measurement items for the constructs of our research model were derived from previous studies and are included in Appendix 2. Each construct was based on three to five items. The items for the UTAUT2 constructs were adapted from Venkatesh et al. (2003) and Venkatesh et al. (2012). The items for measuring trust (benevolence) were adapted from Mayer and Davis (1999). The items for measuring mastery approach goals were adapted from Elliot and McGregor (2001) and the items for personal innovativeness in information technology were adapted from Yi et al. (2006). A total of 41 measurement items were adapted from prior studies and each item was carefully rephrased for the agricultural data collection context using mobile SMS (Appendix 2). Each item was measured with a five-point Likert scale, ranging from "Strongly disagree" (1) to "Strongly agree" (5).

### 5.2. Respondents, sampling and data collection

The respondents formed two groups. The first comprised of farmers who have participated in mobile SMS for agricultural data collection experiment. These farmers were called "SMS farmers". The second comprised of farmers who have mobile phones but did not participate in the mobile SMS agricultural data collection experiment. These farmers are called "Non SMS farmers". The survey was conducted in a face-to-face interview with both groups of farmers, and all participants were randomly selected from the list of farmers participating in the N2Africa and Sesame Business Network projects; multi-group analysis was conducted to control for and explore the possible influence of group membership. During the selection process, an equal number of respondents from each group were selected per Kebele (smallest administrative unit). A total of 220 responses with no missing values were collected and all were used in the analysis. Oral informed consent was obtained from all respondents, who were already participating in the ongoing N2Africa and Sesame Business Network projects.

### 5.3. Data analysis

The demographic data was first analysed using descriptive statistics. We conducted Structural Equation Modelling (SEM) to test our research model (Figure 1). SEM is a set of statistical models that seek to explain the relationships between multiple variables (Hair et al. 2010). SEM was used as a preferable method compared to regression as it allows simultaneous analysis of all relationships, combining multiple regression with factor analysis, while also allowing for both observed and latent variables to be analysed at the same time, and providing overall fit statistics (Tabachnick and Fidell 2007; Gefen et al. 2000). Moreover, SEM takes into account measurement errors within observed variables (Hair et al. 2010; Gefen et al. 2000). It has also been identified that SEM is an appropriate covariance-based approach for studies like ours with a strong basis on 'a priori' theory (e.g., Hung et al. 2013). Following the recommendations of Anderson and Gerbing (1988), the analysis was done in two steps. First, confirmatory factor analysis (CFA) was conducted using Maximum Likelihood Estimation method to examine reliability and validity of our measurement model (Outer model). Second, we evaluated the path analysis of the structural model (Inner model) estimates to test the significance of our hypotheses and the predictive power of the proposed model for this study (Figure 1).

The overall fit of the measurement and structural models were assessed using a combination of absolute and relative indexes: normed chi-square (CMIN/DF), Adjusted Goodness-of-Fit Index (AGFI), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation

(RMSEA). For both the measurement and structural models to have sufficiently good fit, these measures needed to be $< 3$, $\geq 0.8$, $\geq 0.95$, and $\leq 0.7$ respectively (Hair et al. 2010; Hu and Bentler 1999). For the structural model, the strength and significance of the relationship between each of the constructs and behavioural intention was assessed using standardised regression weights (SRW) and p-value ($p < 0.05$).

Prior to the path analysis (hypotheses testing), the measurement model was also assessed for (i) construct reliability, (ii) indicator reliability, (iii) convergence validity, and (iv) discriminant validity. Construct reliability is a measure of internal consistency of the measurement items and was assessed using composite reliability (CR) and Cronbach's alpha values (Nunnally and Bernstein 1994; Straub 1989). The indicator reliability was evaluated based on factor loadings (Churchill 1979). Convergence validity measures whether items can effectively reflect their corresponding construct (i.e., converge on the intended construct), whereas discriminant validity measures whether two constructs are statistically and theoretically different (Hair et al. 2010). Average variance extracted (AVE) was used as the criterion to test convergence validity (Fornell and Larcker 1981). To examine discriminant validity, we compared the square root of AVE and factor correlation coefficients (Fornell and Larcker 1981).

Prior to assessing the measurement and structural models, Common Method Variance (CMV) and multicollinearity were tested. The Common Latent Factor (CLF) method was applied to test Common Method Variance (CMV) (Podsakoff et al. 2003). No factor was found to account for the majority of the variance in the variables, confirming that the common method variance is not a concern in the data. Moreover, to test multicollinearity, Variance Inflation Factors (VIFs) and tolerance were computed for different constructs in our model and they were found to be less than the threshold of 3 and greater than 0.1 respectively, suggesting that multicollinearity was not a major issue in our study (O'brien 2007).

Furthermore, multi-group analysis was performed to assess the moderation effect of farmer's characteristics (age and experience) between UTAUT2 constructs and behavioural intention (Figure 1). For the factor age, respondents were divided into two groups based on the mean age: (1) "Younger farmers" who were less than 43 years old (*n* = 115), and (2) "Older farmers" who were 43 years and older (*n* = 105) at the time of the data collection. To examine the moderation effect of experience, the data were divided into two groups. The first group consisted of farmers who participated in the mobile SMS experiment (i.e. "SMS Farmers", *n* = 110), and the second group consisted of farmers who did not participate in the mobile SMS experiment (i.e. "Non SMS farmers", *n* = 110). The moderator variable of the UTAU2 model 'gender' was not further considered in the analysis because there were few female farmers who participated in the study.

As part of the multi-group analysis, measurement model invariance, which includes configural and metric invariance, was assessed following a step-by-step procedure presented in Steenkamp and Baumgartner (1998). Configural invariance checks if the factor structure is invariant across groups, indicating that the participants from the different groups understand the constructs in the same way (Milfont and Fischer 2015). Metric invariance tests if different groups respond to the items in the same way. That is, it checks if the strengths of the relations between specific items and their respective underlying construct (i.e. factor loadings) are the same across groups (Milfont and Fischer 2015).

To assess configural invariance, unconstrained multi-group measurement models which allow factor loadings to vary across the two groups (i.e. between "SMS farmers" and "Non SMS farmers" and between "Younger farmers" and "Older farmers") were developed. The model fit for the configural invariance between "SMS farmers" and "Non SMS farmers" was satisfactory (CMIN/DF = 1.518; CFI = 0.910; RMSEA = 0.049), and between "Younger farmers" and "Older farmers" it was also satisfactory (CMIN/DF = 1.381; CFI = 0.934; RMSEA = 0.042)

(Milfont and Fischer 2015). This implied that the models fit both groups well and configural invariance was met.

To assess metric invariance, fully constrained measurement models that constrain the measurement weights (i.e., factor loadings) for each measured variable to be equal for the two groups (i.e. between "Younger farmers" and "Older farmers" and between "SMS farmers" and "Non SMS farmers") were developed. Fit indices for the fully constrained measurement model between "SMS farmers" and "Non SMS farmers" were satisfactory (CMIN/DF = 1.569; CFI = 0.90; RMSEA = 0.051), and between "Younger farmers" and "Older farmers" they were also satisfactory (CMIN/DF = 1.360; CFI = 0.934; RMSEA = 0.041). The results of the fully constrained measurement models were compared to those of the unconstrained multi-group measurement models using chi-square difference test. The chi-square difference test for the two groups were not significant, suggesting metric invariance for the two groups was also met (Milfont and Fischer 2015). After meeting the criteria of both configural and metric invariance at the measurement model level, invariance analysis at the structural model level was assessed.

# 6. Results

## 6.1. Descriptive statistics

The characteristics of the farmers who participated in this study are presented in Table 1. The majority of the respondents were male (91.8%). Respondent's age fell predominantly between 31 – 50 years old (56.8%), and the education level was mainly primary school (70.9%). The majority of the respondents (62.7%) have been using mobile phones for the last 6 – 10 years.

**Table 1: Demographic characteristics of the surveyed farmers**

| Factor | Frequency | Percentage (%) |
|---|---|---|
| **Gender** | | |
| Male | 202 | 91.8 |
| Female | 18 | 8.2 |
| **Age (years)** | | |
| 21 – 30 | 37 | 16.8 |
| 31 – 40 | 66 | 30.0 |
| 41 – 50 | 59 | 26.8 |
| 51 – 60 | 42 | 19.1 |
| 61 – 70 | 12 | 5.5 |
| 71 or older | 4 | 1.8 |
| **Education level** | | |
| Illiterate | 9 | 4.1 |
| Can read & write | 13 | 5.9 |
| Primary school | 156 | 70.9 |
| Secondary school | 24 | 10.9 |
| Higher education | 18 | 8.2 |
| **Years of using mobile phone** | | |
| 0 - 5 years | 56 | 25.5 |
| 6 - 10 years | 138 | 62.7 |
| 11 years and more | 26 | 11.8 |
| **Marital status** | | |
| Married | 192 | 87.3 |
| Single | 28 | 12.7 |

### 6.2. Measurement model results

The first fit of the measurement model including all the items of the constructs was not sufficient. Therefore, following the suggestions from the analysis of the model fit indices, standardised regression weights and covariance modification indices, as it was also done by Slade et al. (2015), it was decided to remove the items SI3 and SI4 (Appendix 2). This improved the model fit indices and resulted in a "good measurement model" (Gefen et al. 2000) with the following index values: CMIN/DF: 1.250; AGFI: 0.824; CFI: 0.969; and RMSEA: 0.034 (Table 2).

The measurement model was also further adapted based on an assessment of (i) construct reliability, (ii) indicator reliability, (iii) convergence validity, and (iv) discriminant validity. As shown in table 3, all the constructs have composite reliability (CR) and Cronbach's alpha values greater than 0.7, indicating the construct's reliability criterion was achieved (Nunnally and Bernstein 1994; Straub 1989). The indicator reliability was evaluated based on the criteria that item loading should be higher than 0.7 and that every item with loading less than 0.4 should be eliminated (Churchill 1979). Two items, EE2 and HA3 were dropped because of low factor loading. The factor loadings for the remaining items are greater than the threshold value of 0.7, confirming a good indicator reliability of the instrument (Table 3). The convergence validity was tested with the Average Variance Extracted (AVE) value (Fornell and Larcker 1981). As shown on table 3, all the constructs have an AVE greater than the minimum acceptable value of 0.5 confirming the convergence validity criterion was achieved.

Discriminant validity was analysed using Fornell-Larcker criterion. Table 4 contains the square root of the AVE in bold along the diagonal, confirming the condition of being greater than the correlation between the constructs (Fornell and Larcker 1981). The overall results of the measurement model indicate that the model has good indicator and construct reliability, and convergence and discriminant validity, confirming that the constructs are statistically distinct and can be used to test the path analysis of the structural model.

**Table 2**: Summary of fit indices for the measurement and structural models

| Model fit indices | Recommended value | Model results | Reference |
|---|---|---|---|
| Normed chi-square (CMIN/DF) | < 3 | 1.250 | (Hair et al. 2010; Hu and Bentler 1999) |
| Adjusted Goodness-of-Fit Index (AGFI) | ≥ 0.8 | 0.824 | (Etezadi-Amoli and Farhoomand 1996) |
| Comparative Fit Index (CFI) | ≥ 0.95 | 0.969 | (Hair et al. 2010; Hu and Bentler 1999) |
| Root Mean Square Error of Approximation (RMSEA) | ≤ 0.7 | 0.034 | (Hair et al. 2010; Hu and Bentler 1999) |
| TLI (Tucker-Lewis Index) | Approaches 1 | 0.964 | (Byrne 2001) |

**Table 3**: Summary of reliability and validity measures of the measurement model

| Construct | Number of items | Composite reliability (CR) | Cronbach's alpha | AVE | Factor loadings |
|---|---|---|---|---|---|
| BI | 3 | 0.783 | 0.777 | 0.546 | 0.70 – 0.80 |
| PE | 4 | 0.892 | 0.891 | 0.676 | 0.79 – 0.87 |
| HA | 4 | 0.863 | 0.857 | 0.681 | 0.79 – 0.84 |
| TR | 5 | 0.917 | 0.905 | 0.689 | 0.78 – 0.90 |
| PV | 3 | 0.812 | 0.797 | 0.591 | 0.78 – 0.79 |
| FC | 4 | 0.857 | 0.851 | 0.601 | 0.75 – 0.84 |
| SI | 4 | 0.811 | 0.809 | 0.683 | 0.75 – 0.80 |
| HM | 3 | 0.885 | 0.869 | 0.722 | 0.82 – 0.92 |
| IN | 3 | 0.837 | 0.824 | 0.633 | 0.77 – 0.87 |
| MAG | 3 | 0.922 | 0.919 | 0.799 | 0.89 – 0.94 |
| EE | 4 | 0.814 | 0.810 | 0.594 | 0.74 – 0.79 |

***Note:*** AVE=Average Variance Extracted, BI=Behavioural intention, PE=Performance expectancy, HA=Habit, TR=Trust, PV=Price value, FC=Facilitating conditions, SI=Social influence, HM=Hedonic motivation, IN= Innovativeness, MAG= Mastery approach goals, and EE=Effort expectancy.

**Table 4:** Square root of Average Variance Extracted (AVE) in bold on diagonal and factor correlation coefficients

| | BI | PE | HA | TR | PV | FC | SI | HM | IN | MAG | EE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **BI** | **0.739** | | | | | | | | | | |
| **PE** | 0.324 | **0.822** | | | | | | | | | |
| **HA** | 0.373 | 0.146 | **0.825** | | | | | | | | |
| **TR** | 0.329 | 0.070 | 0.100 | **0.830** | | | | | | | |
| **PV** | 0.476 | 0.292 | 0.454 | 0.196 | **0.769** | | | | | | |
| **FC** | 0.163 | 0.135 | 0.224 | 0.119 | 0.205 | **0.775** | | | | | |
| **SI** | 0.224 | 0.294 | 0.062 | 0.136 | 0.278 | -0.049 | **0.826** | | | | |
| **HM** | 0.201 | 0.138 | 0.073 | -0.006 | 0.144 | -0.037 | 0.332 | **0.850** | | | |
| **IN** | 0.187 | 0.155 | 0.140 | 0.145 | 0.391 | 0.254 | 0.029 | -0.070 | **0.796** | | |
| **MAG** | 0.079 | -0.083 | 0.080 | 0.159 | 0.014 | 0.001 | -0.174 | -0.024 | 0.202 | **0.894** | |
| **EE** | 0.350 | 0.076 | 0.477 | -0.078 | 0.367 | 0.442 | 0.072 | 0.119 | 0.342 | -0.035 | **0.771** |

***Note:*** BI=Behavioural intention, PE=Performance expectancy, HA=Habit, TR=Trust, PV=Price value, FC=Facilitating conditions, SI=Social influence, HM=Hedonic motivation, IN= Innovativeness, MAG= Mastery approach goals, and EE=Effort expectancy.

### 6.3. Structural model results

After assessing the measurement model, the structural model (path analysis) was assessed. The overall model fit for the structural model was also good (Table 2). Values of the indices CMIN/DF, AGFI, CFI, and RMSEA were the same as the measurement model. The path analysis revealed that four of the ten hypotheses are supported (Table 5). Significant positive impacts on behavioural intention (BI) were found for performance expectancy (PE) (confirming H1), effort expectancy (EE) (confirming H2), price value (PV) (confirming H6) and trust (TR) (confirming H9). However, no significant relationships were observed between behavioural intention and the other constructs implying the hypotheses (H3, H4, H5, H7, H8 and H10) could not be supported. The four significant constructs explained 41% of the variance in behavioural intention to use mobile SMS for agricultural data collection.

**Table 5:** Summary of results of path analysis of the structural model

| Hypothesis | Structural Path | Estimates | | Result |
|---|---|---|---|---|
| | | SRW | *p*-Value | |
| H1 | PE → BI | 0.211 | **0.007****| Supported |
| H2 | EE → BI | 0.273 | **0.013*** | Supported |
| H3 | SI → BI | 0.011 | 0.899 | Not supported |
| H4 | FC → BI | -0.065 | 0.438 | Not supported |
| H5 | HM → BI | 0.090 | 0.230 | Not supported |
| H6 | PV → BI | 0.249 | **0.015*** | Supported |
| H7 | HA → BI | 0.084 | 0.355 | Not supported |
| H8 | IN → BI | -0.081 | 0.363 | Not supported |
| H9 | TR → BI | 0.286 | **0.000**** | Supported |
| H10 | MAG → BI | 0.071 | 0.329 | Not supported |

***Note:*** BI=Behavioural intention, PE=Performance expectancy, EE=Effort expectancy, SI=Social influence, FC=Facilitating conditions, HM=Hedonic motivation, PV=Price value, HA=Habit, IN= Innovativeness, TR=Trust, MAG= Mastery approach goals, SRW = Standardized Regression Weight;

*: Significant at $p < 0.05$ and **: Significant at $p<0.01$

### 6.4. Multi-group analysis results

After establishing configural and metric invariance at the measurement model level, multi-group analyses were conducted at the structural level to determine if participating in the SMS experiment (‘experience’) and age had a moderation effect. Because the complexity did not allow for including all variables, and no hypotheses were available for the added constructs, the included variables were limited by the ones from UTAUT2.

Individual path analysis showed that the effect of price value on behavioural intention was significantly higher for “Non SMS farmers” compared to “SMS farmers” (Table 6). The standardised regression weights (SRW) revealed that price value was significant for those farmers who did not participate in the mobile SMS experiment, but not for those who participated in the experiment. The effect of performance expectancy on behavioural intention was significantly higher for younger (and significant) compared to older farmers (not significant) (Table 7). The effect of facilitating conditions on behavioural intention narrowly missed significance ($p$ = 0.056), but was higher for older farmers.

**Table 6**: Multi-group analysis between farmers participating in the mobile SMS experiment ("SMS farmers") and those who did not participate ("Non SMS farmers")

| Structural path | **SMS farmers** | | **Non SMS farmers** | | $\triangle\chi^2$ | $\triangle$df | *p*-Value |
|---|---|---|---|---|---|---|---|
| | SRW | *p*-Value | SRW | *p*-Value | | | |
| PE → BI | -0.015 | 0.896 | 0.138 | 0.197 | 1.142 | 1 | 0.285 |
| EE → BI | -0.081 | 0.632 | 0.041 | 0.748 | 0.262 | 1 | 0.608 |
| SI → BI | 0.072 | 0.520 | 0.034 | 0.770 | 0.004 | 1 | 0.951 |
| FC → BI | -0.027 | 0.801 | 0.001 | 0.991 | 0.013 | 1 | 0.908 |
| HM → BI | -0.167 | 0.094 | 0.133 | 0.241 | 3.066 | 1 | 0.080 |
| PV → BI | 0.221 | 0.099 | 0.532 | **0.000*** | 10.763 | 1 | **0.001*** |
| HA → BI | 0.638 | 0.001 | 0.086 | 0.440 | 0.948 | 1 | 0.330 |

SRW = Standardized Regression Weight; $\chi^2$ = chi-square; df = degree of freedom; *: Significant at $p < 0.01$

**Table 7**: Multi-group analysis between younger and older farmers

| Structural path | **Younger farmers** | | **Older farmers** | | $\triangle\chi^2$ | $\triangle$df | *p*-Value |
|---|---|---|---|---|---|---|---|
| | SRW | *p*-Value | SRW | *p*-Value | | | |
| PE → BI | 0.392 | **0.000*** | -0.008 | 0.947 | 4.586 | 1 | **0.032*** |
| EE → BI | 0.157 | 0.225 | 0.121 | 0.431 | 0.005 | 1 | 0.943 |
| SI → BI | -0.083 | 0.483 | 0.146 | 0.271 | 1.636 | 1 | 0.201 |
| FC → BI | -0.232 | 0.052 | 0.115 | 0.370 | 3.665 | 1 | 0.056 |
| HM → BI | 0.100 | 0.311 | 0.067 | 0.562 | 0.028 | 1 | 0.868 |
| PV → BI | 0.356 | 0.034 | 0.314 | 0.023 | 0.215 | 1 | 0.643 |
| HA → BI | 0.111 | 0.423 | 0.056 | 0.655 | 0.139 | 1 | 0.709 |

SRW = Standardized Regression Weight; $\chi^2$ = chi-square; df = degree of freedom; *: Significant at $p < 0.05$

## 7. Discussion and implications

### 7.1. Constructs affecting behavioural intention

The factors that were found to positively influence farmer's intention to adopt mobile SMS for agricultural data provision are performance expectancy, effort expectancy, price value and trust (Figure 1; Table 5). The three factors from the UTAUT2 model explained 32%, while adding the construct of trust increased this to 41% of the variance in farmer's intention to adopt mobile SMS. This indicates the importance of tailoring technology adoption models originally developed for the organisational context to other contexts like mobile data services (e.g. SMS) (Baptista and Oliveira 2015).

The finding of the relationship of performance expectancy with behavioural intention (H1) is consistent with earlier studies in consumers SMS adoption (Kim et al. 2008), mobile banking (Baptista and Oliveira 2015; Oliveira et al. 2014), and SMS advertising (Muk and Chung 2015). In the agricultural domain, studies also found the importance of performance expectancy on the intention of farmers to adopt decision support tools (Rose et al. 2016), precision agriculture (D'Antoni et al. 2012; Adrian et al. 2005) and dairy farming technology (Flett et al. 2004).

The research model validated the positive relationship between effort expectancy and behavioural intention (H2). This implies that farmers, who perceive that sending SMS requires low effort, have a high intention to adopt the mobile SMS for data collection. The finding is consistent with other studies in consumers SMS adoption (Kim et al. 2008), and farmers adoption of decision support systems (Rose et al. 2016) and precision agriculture (Aubert et al. 2012). This finding is also relevant with regard to the question which data collection method to use: while more advanced methods such as smartphones and tablets may be available, the selected method should be suitable for the target community.

The other core factor from the UTAUT2 constructs that has a significant impact on mobile SMS adoption is price value. This implies that the lower the costs for using the mobile SMS, the higher the intention for the farmers to adopt mobile SMS for agricultural data collection. Similar results were found by studies in adoption of decision support tools (Rose et al. 2016).

The results (Table 5) show that social influence (H3), facilitating conditions (H4), hedonic motivation (H6), habit (H7), personal innovativeness (H8) and mastery-approach goals (H10) were not found to predict behavioural intention to adopt mobile SMS. As farmers in the current study have a collectivistic culture, it was anticipated that social influence would positively affect behavioural intention to adopt mobile SMS, but this was not the case. This implies that farmers will not simply adopt a technology because important others (e.g. friends or neighbours) are using the technology. The lack of the effect of facilitating conditions is consistent with what was reported in earlier studies (Baptista and Oliveira 2015; Im et al. 2011). When there is a facilitating condition (e.g., resources, getting support from extension workers) to help farmers to use mobile SMS for agricultural data collection, they do not give it much importance (Baptista and Oliveira 2015). The low importance of hedonic motivation shows that farmers do not enjoy using mobile SMS technology. The low importance of habit can be explained by the fact that the farmers did not have previous experience of using mobile SMS for agricultural data collection and hence it is not yet their habit. The low importance of mastery–approach goals indicate that farmers did not believe that using mobile SMS will help them to improve their level of competence in crop production. Farmers are already using mobile phones (e.g., to access market and weather information) in Ethiopia (Beza et al. 2017). As a result, they may not consider using the SMS feature of the phone as being innovative.

### 7.2. Implications for citizen science in agriculture

In this study, it was revealed that performance expectancy, effort expectancy, price value and trust are the most important factors for the farmers to adopt mobile SMS for data collection. Among these factors, trust is the strongest predictor of farmers' intention to adopt mobile SMS to provide their farm related information. This clearly signals that in order to use the citizen science approach in the agricultural domain, establishing a trusted relationship with the smallholder farming community is crucial. Unlike other citizen science participants who can provide observations without caring much about the implementers (e.g. bird watchers), for farmers the trustworthiness of the people or organisation behind the citizen science campaign is important before sharing their farm related information. At the start of agricultural citizen science initiatives, cooperatives and farmers associations would probably be well placed to take the lead to establish relationships between farmers and citizen science initiatives (Aubert et al. 2012), as they already have close relationships with the farmers, and are likely to be perceived as more trustable. Working with local institutes (e.g., research centres and NGOs) which have a good reputation is another alternative to establish initial trust between farmers and citizen science initiatives. Both types of stakeholders (research centres and NGOs) participated in the two projects (N2Africa and SBN) in which the citizen science experiments in this study were performed.

Given that performance expectancy significantly predicted farmer's behavioural intention to adopt mobile SMS, managers of agricultural citizen science projects need to ensure that using mobile SMS for agricultural data collection offers utilitarian benefits to the farmers. For example, providing location specific agronomic advice or feedback based on the data received by SMS, which can help the farmers in their management decisions to improve agricultural production, can be an option to show the practical benefit of using mobile SMS for data provision (Car et al. 2012; Antonopoulou et al. 2010; Beza et al. 2017).

The multi-group analysis between younger and older farmers revealed that performance expectancy is more important for younger farmers compared to older farmers to adopt mobile SMS (Table 7). The possible reason for this may be younger farmers are less experienced with farming and hence demand more external information (Taragola and Van Lierde 2010;

Schnitkey et al. 1992). Therefore, they expect using mobile SMS will create an opportunity to access information related to farming and also enable them to interact with agronomic experts. For agricultural citizen science initiatives, planning to provide agronomic advice based on the data received, the result highlights the importance of tailoring advises for farmers based on farmer's characteristics (e.g. age).

The comparison between experienced (i.e. "SMS farmers") and unexperienced farmers (i.e. "Non SMS farmers") shows that the price value is more important for the "Non SMS farmers" compared to the "SMS farmers" to adopt mobile SMS (Table 6). The reason that price value was relatively less important for "SMS farmers" is that in the studied setting the costs of sending the SMS were covered by the projects, and not by the farmers who participated in the experiment. The fact that price value was specifically important for "Non SMS farmers" indicates that projects implementing citizen science need to find a mechanism where the SMS data transmission is free of charge (e.g. by providing free airtime).

### 7.3. Implications for mobile app developers and policy makers

The importance of effort expectancy on farmer's intention to adopt mobile SMS clearly indicates that mobile phone software developers need to develop easy to use SMS apps. Iannone Iii et al. (2012), in a study of citizen science to assess the abundance of earthworms, stated that a data collection method for citizen science must meet three criteria: (1) ease, (2) safety, and (3) reliability. To simplify the data collection process, applications that support Interactive Voice Response (IVR) (e.g. Robinson and Obrecht 2016) and icon-based user interfaces can potentially be developed (e.g. Herrick et al. 2016; Vitos et al. 2013). The study of Wyche and Steinfield (2016) discovered a mismatch between the design of market information services (MIS) and smallholder farmers' perceptions of their mobile phones' communication capabilities. While designing mobile SMS applications for agricultural data collection, the farming community needs to be considered (Alvarez and Nuthall 2006) and applications need to be developed following the design principles for low-literacy users (Medhi et al. 2011).

In other sectors (e.g. forestry), researchers have shown the high potential of local communities using mobile phones for national forest monitoring (Pratihast et al. 2013). The lessons learnt from the forestry sector can also be extended to the agricultural domain. To integrate ICT tools like mobile phones in the agricultural sector to collect agricultural information or food security indicators in developing countries (e.g. Hammond et al. 2016) directly from the farmers, there needs to be an enabling environment. As most of the farmers in the rural areas are low-literate, the use of mobile phones for data collection need to be supported by the agricultural extension system.

### 7.4. Limitations and future research

Despite its contributions regarding factors that are important for smallholder farmers to adopt mobile SMS for agricultural citizen science, some limitations merit discussion. First, since half of the farmers participated in this study did not experience the use of mobile SMS for agricultural data collection, we did not examine the effect of behavioural intention on use behaviour. Therefore, it is recommended that future research takes a longitudinal approach which would enable the examination of the effect of behavioural intention on farmers use behaviour. Longitudinal research would also allow to asses if the importance of the constructs would change over time. For example, the effect of trust on farmers' behavioural intention to use mobile SMS might become unimportant when farmers trust towards the people and/or organisation managing the citizen science initiative develops. Second, the study does not claim to statistically represent farmers in Ethiopia (e.g. in terms of gender), so it would be interesting to test the model with more female farmers. Finally, the important factors for technology adoption might differ from location to location, so assessing the validity of this model with farmers across different cultures both in developed and developing countries would be theoretically and practically useful. Relatedly, this study set out to investigate an SMS-based data collection approach within the specific context of the Ethiopian infrastructure, so care must be taken to generalise to other geographies with other telecommunication infrastructures. Also, SMS-based data collection will likely be replaced with other modalities of data exchange (e.g. via apps), depending on factors such as penetration of broadband cellular network technology and smartphone ownership. Therefore, the present results need to be investigated for other devices in future research to further test the validity of the conceptual model.

## 8. Conclusion

Trust was found to be the strongest predictor of farmers' intention to adopt mobile SMS to provide their farm related information. This clearly highlights the importance of establishing a trusted relationship with the farming community in order to utilize the full potential of citizen science in the agricultural domain. In addition, managers of agricultural citizen science projects need to ensure that using mobile SMS for agricultural data collection offers utilitarian benefits to the farmers. Further, the technology that will be used as part of the digital citizen science need to be easy to use by the farmers. Moreover, the cost of using the technology need to be affordable by the farmers and whenever possible, the citizen science projects need to cover the data transmission cost. Multi-group analysis using farmer's characteristics age and experience as moderator variables revealed that performance expectancy was important for younger farmers; whereas price value was important for farmers who did not participate in a mobile SMS experiment.

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**Appendix 1. List of factors and associated group names**

| List of activities | Group name |
|---|---|
| Start/end of land clearing<br>Start/end of land cleaning<br>Start/end of first ploughing<br>Start/end of second ploughing<br>Start/end of third ploughing<br>Start/end of row making | **Land preparation** |
| Start/end of sowing/planting<br>Start/end of gap filling<br>Start/end of thinning | **Planting** |
| Start/end of 1st weeding<br>Start/end of 2nd weeding<br>Start/end of 3rd weeding | **Weeding** |
| Date of Emergence<br>Date of full canopy closure (no bare soil to be seen)<br>Start/end of flowering<br>Full flowering<br>Crop reaching full maturity (yellowed and ready for harvest)<br>Start/end of harvesting | **Crop characteristics** |
| Start/end of fertilizer application | **Fertilization** |
| Start/end of pest scouting<br>Start/end of pest control/chemical application in the field | **Crop protection** |
| Start/end of preparing drying spots<br>Start/end of threshing<br>Start/end of winnowing and cleaning<br>Start/end of bagging sesame in the field<br>Start/end of loading sesame bags for transporting to store (home) | |

| | |
|---|---|
| Start/end of transporting sesame bags to store (home)<br>Start/end of (un)loading sesame bags in the store (home)<br>Start/end of chemical application in the store (home)<br>Start/end of loading bags for transporting sesame to market<br>Start/end of transporting bags to market<br>Start/end of unloading bags in the market | **Postharvest handling** |

## Appendix 2. Questionnaire to assess mobile SMS technology acceptance of farmers

The main purpose of this survey is to assess the SMS technology acceptance of farmers as a data provision tool to provide agricultural information for yield gap analysis.

### 1. <u>Background information</u>

1.1. Date of interview: ____________________1.2. Region: ___________________________
1.3. District/Woreda: ____________________ 1.4. Kebele/Village: ______________________

### 2. <u>Introduction</u>

Introduce yourself and explain the purpose of the survey as it will mainly be used for research purpose and assure the interviewee of the confidentiality. Please check if the farmer has any questions at this time.

### 3. <u>General information of the respondent</u>

3.1. Name of the respondent: ____________________________ 3.2. Gender: Male [] Female []
3.3. Age (years): _____ 3.4. Marital status: ____________________
3.5. Educational level (grade/illiterate): _______________________
3.6. Distance to the nearest city (Min) ________________

### 4. <u>Mobile phone information</u>

4.1. Mobile number: _____________________
4.2. Number of years of using mobile phone _______(Years)_________(Months)
4.3. Did you send SMS in the 2014/2015 growing season about the N2Africa/SBN 20 steps field?
Yes [] No []
4.4. If yes, how many SMS messages did you send over the growing season? ________________
4.5. Did you use another mobile number to send SMS about the N2Africa/SBN 20 steps field?
Yes [] No []
4.6. If yes, mobile number(s) used to send SMS about the N2Africa/SBN 20 steps field ___________
4.7. Did you ever send SMS before you participate in N2Africa/SBN SMS pilot data collection campaign? Yes [] No []
4.8. What do you prefer to provide agronomic information? Calling [] SMS messaging [] Face-to-face [] Other: ________________

**Read [the following scripted introduction]**

Dear [name of farmer] first I would like to thank you once again for participating in this interview. The questions I ask you after this point are related to your mobile phone, mainly the use of your mobile phone to send agronomic information using short message system (SMS). Thank you for your valuable time and we will proceed to the questions. Please indicate the degree to which you agree with each statement by using the scale 1 (Disagree strongly) to 5 (Agree strongly).

**Measurement items**

| Constructs | Items | No. | Source |
|---|---|---|---|
| Behavioural intention (BI) | - I intend to use or continue using mobile SMS messaging in the future | BI1 | (Venkatesh et al. 2012; Venkatesh et al. 2003) |
| | - I will always try to use mobile SMS messaging in my daily life | BI2 | |
| | - I plan to use or continue using mobile SMS messaging frequently | BI3 | |
| Performance expectancy (PE) | - I find mobile SMS messaging useful in my daily life | PE1 | (Venkatesh et al. 2012; Venkatesh et al. 2003) |
| | - Using mobile SMS messaging increases my productivity | PE2 | |
| | - Using mobile SMS messaging helps me accomplish things more quickly in the farm | PE3 | |
| | - Using mobile SMS messaging increases my chances of achieving high crop productivity | PE4 | |
| Effort expectancy (EE) | - Learning how to use mobile SMS messaging is easy for me | EE1 | (Venkatesh et al. 2012; Venkatesh et al. 2003) |
| | - My interaction with mobile SMS messaging is clear and understandable | EE2 | |
| | - I find mobile SMS messaging easy to use | EE3 | |
| | - It is easy for me to become skilful at using mobile SMS messaging | EE4 | |
| Social influence (SI) | - People who are important to me think that I should use mobile SMS messaging | SI1 | (Venkatesh et al. 2012; Venkatesh et al. 2003) |
| | - People who influence my behaviour think that I should use mobile SMS messaging | SI2 | |
| | - People whose opinions that I value prefer that I use mobile SMS messaging | SI3 | |
| | - People who are important to me would use mobile SMS messaging themselves | SI4 | |
| Facilitating conditions (FC) | - I have the resources necessary to use mobile SMS messaging | FC1 | (Venkatesh et al. 2012; Venkatesh et al. 2003) |
| | - I have the knowledge necessary to use mobile SMS messaging | FC2 | |

| | | | |
|---|---|---|---|
| | - Mobile SMS messaging is compatible with other technologies I use | FC3 | |
| | - I can get help from others (e.g.  extension workers or children ) when I have difficulties using mobile SMS messaging | FC4 | |
| Hedonic motivation (HM) | - Using mobile SMS messaging is fun | HM1 | (Venkatesh et al. 2012) |
| | - Using mobile SMS messaging is enjoyable | HM2 | |
| | - Using mobile SMS messaging is very entertaining | HM3 | |
| Price value (PV) | - Mobile SMS messaging is reasonably priced | PV1 | (Venkatesh et al. 2012) |
| | - Mobile SMS messaging is a good value for the money | PV2 | |
| | - At the current price, mobile SMS messaging provides a good value | PV3 | |
| **Constructs** | **Items** | **No.** | **Source** |
| Habit (HA) | - The use of mobile SMS messaging has become a habit for me | HA1 | (Venkatesh et al. 2012) |
| | - I am addicted to using mobile SMS messaging | HA2 | |
| | - I must use mobile SMS messaging | HA3 | |
| | - Using mobile SMS messaging has become natural to me | HA4 | |
| Trust (TR) | - SBN[1]/N2Africa is very concerned about my sesame/chickpea[2] crop production | TR1 | (Mayer and Davis 1999) |
| | - My needs and desires are very important to SBN/N2Africa | TR2 | |
| | - SBN/N2Africa would not knowingly do anything to hurt me | TR3 | |
| | - SBN/N2Africa really looks out for what is important to me | TR4 | |
| | - SBN/N2Africa will go out of its way to help me | TR5 | |
| Mastery-approach goals (MAG) | - I want to learn as much as possible about sesame/chickpea crop production | MAG1 | (Elliot and McGregor 2001) |
| | - It is important for me to completely understand the recommendations provided by SBN/N2Africa about sesame/chickpea crop production | MAG2 | |
| | - I desire to completely master sesame/chickpea crop production | MAG3 | |
| Innovativeness (IN) | - If I heard about a new technology, I would look for ways to experiment with it | IN1 | (Yi et al. 2006) |
| | - Among my peers, I am usually the first to explore new gadgets & technologies | IN2 | |
| | - I like to experiment with new technologies | IN3 | |

[1] Sesame Business Network

[2] The word sesame was used while surveying farmers in the Sesame Business Network project and chickpea was used for N2Africa farmers.

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