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Smartphone apps as a new method to collect data on smallholder farming systems in the digital age: A case study from Zambia

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ABSTRACT

Across the developing world, the spread of mobile- and smartphones has led to a surge in mobile services for rural populations. While the potentials of mobile services to provide development opportunities for smallholder farmers are widely acknowledged, the potentials to use smartphone applications to collect data on smallholder farming systems are little explored. Yet, researchers studying farming systems need good quality data. So far, data on smallholder farming systems is typically collected using household surveys. Survey questions are prone to recall biases, however, which can be substantial. This paper assesses whether smartphone can be used to collect data in real time and thus increase the accuracy of socioeconomic and agronomic data collection. In this paper, we present a smartphone application that was developed for this purpose. We use the application to analyze the effects of agricultural mechanization on intra-household time-use and nutrition in rural Zambia. While the early, descriptive results shed interesting light on the effects of mechanization, the contribution of this study is primarily methodological. The study highlights the potentials of using smartphone applications to collect socioeconomic and agronomic data on smallholder-farming systems, potentially in real time. It also suggests ways to combine data recorded by respondents with built-in sensors of smartphones and external sensors and thus shows fascinating new pathways for researchers in the digital age.

1. Introduction

Across the developing world, ownership of mobile phones is rapidly increasing (ITU, 2016). This has led to a surge of mobile tools, which help smallholder farmers to access agricultural, health, educational, and financial services (Baumüller, 2012). The more recent rise of smartphones now creates possibilities to also use applications that are based on visual tools (which make them usable for users with no or low literacy levels) and that may work with data obtained from in-built sensors. There is a consensus, that such applications offer new potentials for smallholders to improve their agricultural production systems. For example, smallholder farmers in the Senegal may use a cloud-based decision-support tool to apply fertilizer more accurately (Saito et al., 2015). And Argentinian farmers may use a smartphone app to better time fungicide applications (Carmona et al., 2018). These examples show the potentials that apps offer for farmers. However, they may also provide new opportunities for researchers to collect data in complex smallholder farming systems. So far, these potentials have been little explored.

For socioeconomic studies, data on smallholder farming systems is typically collected through household surveys. In agronomic studies, there has been an increasing emphasis on on-farm research, partly motivated by donor priorities (De Roo et al., 2017). In on-farm research, there is typically a need to collect not only agronomic data from the field experiments, but also to collect data from the participating farmers through interviews (Van Vugt et al., 2017). As smallholders do not usually keep any records, researchers collecting socioeconomic or agronomic data from smallholders rely on recall questions. There is strong evidence, that the error that may be introduced through recall bias can be substantial (Arthi et al., 2018; Deininger et al., 2012). Increasing the frequency of data collection is, however, associated with major costs. The use of smartphone apps can considerably reduce these costs and increase the accuracy of data collection, if the farmer himself or herself enters data in real time. In this paper, we present a smartphone app that was developed for this purpose. We demonstrate our experience using this app when analyzing the effects of agricultural mechanization on intra-household time-use and nutrition in smallholder farming systems in Zambia.

We chose to focus on mechanization because there has been a renewed interest to promote agricultural mechanization in Africa (Daum

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and Birner, 2017). The intra-household effects of mechanization are, however, ambiguous. Positive effects may include increased income through the expansion of the area that a household cultivates. However, the expansion of the land area cultivated by a household may, increase the burden of labor for activities that are not yet mechanized, such as weeding and harvesting, which are often carried out by women and children (Blackden and Wodon, 2006). The changes in (female) time-use may in turn alter the nutrition status of the household members, including the children (Johnston et al., 2015). Analyzing such intra-household effects requires the collection of data on time-use and nutrition from different household members over an entire cropping season.

Intra-household data is difficult or expensive to collect using conventional methods. Household surveys are prone to large recall biases (Arthi et al., 2018; Juster et al., 2003). Time-use diaries where respondents fill out a 24-h time grid that is divided to 15 or 30 min slots with pre-coded activities, are an alternative, but they are burdensome and difficult to use if respondents cannot read or write and lack a "modern" or clock-based concept of time (Kes and Hema, 2006). Direct observations eliminate recall biases and address the problem of illiteracy and the lack of "modern" concepts of time. However they are expensive and the presence of the researchers may affect the behavior of the observed (Kes and Hema, 2006). The collection of nutrition data faces similar challenges. As a consequence, there is a lack of reliable intra-household data on time-use and nutrition in smallholder farming systems, which makes it difficult for governments and development practitioners to prioritize and design development programs and policies as well as to measure their effects (Johnston et al., 2015).

Against this background, we developed smartphone application called "Time-Tracker". We successfully applied this easy-to-use application in 62 households in the Eastern Province of Zambia. The households were selected to represent different levels of mechanization. The application allowed respondents to record their daily activities and nutritional intake in real-time to avoid recall bias. The application is picture-based so that all user groups can to participate. Altogether, 2790 days of data were collected. While the results shed interesting light on the intra-household effects of mechanization, the contribution of this study is primarily methodological and seeks to highlight the potentials of using smartphone applications as well as sensors to study socioeconomic and agronomic aspects of smallholder farming systems.

2. Methodological considerations

During the last decade, the number of mobile phones has increased rapidly in the developing world (ITU, 2016). In Sub-Saharan Africa, the rate of *unique* mobile subscribers was 43% in 2016, as compared to 66% worldwide (GSMA, 2017). The rate of adults who own a mobile phone was higher than this: for example, 83% and 82% of adults owned a phone in Kenya and Ghana, respectively in 2014 (PEW, 2015). A quarter of phones used are smartphones (GSMA, 2017). In Zambia, even in rural areas 54% of households have at least one person owning a mobile phone (IAPRI, 2016). The growth of mobile phone ownership has led to a surge of mobile services that aim to address the challenges faced by rural populations (Baumüller, 2012; Aker et al., 2016). For example, Saito et al. (2015) developed a cloud-based decision-support tool for field-specific fertilizer recommendation in Senegal. And Bueno-Delgado et al. (2016) developed a tool that helps farmers to minimize fertilizer costs.

While there is widespread consensus about the development opportunities that these mobile services offer, some challenges remain. For example, the text-based nature of most mobile services is a barrier for low- and illiterate users (Aker et al., 2016). The recent rise of smartphones allows developing of visual apps that may also help to overcome the challenges faced by low- and non-literate users. While the rise of smartphones provides new opportunities both with regard to the use of visuals and the use of its built-in sensors, there are still few app-based mobile services (Baumüller, 2016). One of them is "Hello Tractor" – a geo-tracking service that helps farmers to access tractor services in Nigeria, however it still contains text-elements.

While there are several examples of user-oriented mobile services, as shown above, the potentials to use mobile phones as research tools are little explored, especially in the developing world. One notable exception is a pilot study by the Makerere University in Uganda to monitor the spread of pests with camera phones (Quinn et al., 2011). Another exception is an SMS-tool to evaluate the impact of farmer training developed by Technoserve in Tanzania (Baumüller, 2012). One of the first pilot studies to actually use a smartphone application as a research tool in a developing country was done by a research group in rural Bangladesh (Bell et al., 2016). Their application allows participants to answer questions related to social data on a weekly basis. While making a strong case for the use of smartphone apps for research purposes in rural areas, the developed application is still mostly text-based. In brief, there are promising but few attempts to use mobile phones, and especially smartphone apps, as research tools, more importantly, most of the existing apps are text-based thereby excluding low and non-literate users.

In contrast to developing countries, there are already several examples of studies using smartphone apps as research tools in developed countries. Most of them are related to health questions such as "MyHeart Counts" (see https://med.stanford.edu/myheartcounts.html). There are also attempts to use smartphone apps for time-use studies. For example, the Netherlands Institute for Social Research developed an app-based time-use diary to test its viability as a research tool (Fernee and Sonck, 2014). However, this is implicitly based on a cumbersome and imprecise 24-h time grid format and relies on text-based questions. While this attempt show the potentials of using apps for time-use research, it is difficult to use in developing countries where large parts of the population are illiterate or lack a "modern" or clock-based concept of time.

Given the lack of adopted data collection methods for developing countries, there are few studies analyzing time-use within households and even fewer focusing on rural areas in developing countries (Blackden and Wodon, 2006; Johnston et al., 2015). Existing studies frequently rely on survey-questions but are prone to high recall and social desirability errors (Chatzitheochari et al., 2018; Juster and Stafford, 1985). An interesting attempt to find a method for time-use research in developing countries is the use of pictorial-diary-sets which Masuda et al. (2014) pilot-tested with ten household in Ethiopia. The set consisted of a booklet, activity stickers and a timer, which beeps at 30-min intervals. Whenever the timer beeps, respondents would place a sticker in the booklet, which reflected with their activity at that time. While having advantages compared to other data collection methods, this procedure is still cumbersome, does not capture simultaneous activities and is inaccurate given the use of 30 min intervals.

3. Materials and methods

To make use of the fast spread of ICTs and to overcome the challenges of conventional data collection methods, we developed an open source[1], Android-based smartphone application called "Time-Tracker" that allows respondents to record data themselves (see Section 3.1). We applied the app with 62 households in the Eastern Province of Zambia, which represent different levels of farm mechanization (see Section 3.2).

3.1. Data collection technique

The "Time-Tracker" is intuitive and fast to use. The data-entry is

[1] The code can be accessed via https://github.com/HannesBuchwald/TimeTracker.