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Design for Empowerment: Empowering Sri Lankan Farmers through Mobile-based Information System

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Abstract:

We developed a mobile-based information system (MBIS) to empower users to improve their livelihood activities. To do so, we first developed an empowerment framework (since one does not exist) as a basis to develop the MBIS. In particular, we conducted this research to solve an agriculture over-production problem in Sri Lanka where farmers remain trapped in a poverty cycle. They cannot make informed decisions due to lack of access to timely, context-based actionable information to achieve a good revenue. We had to generate some essential information such as current production level in real-time by capturing farmers' decisions such as what and how much to grow. For this purpose, we needed to empower farmers to actively engage them in informed decision-making process through the MBIS. In evaluating the impact of the MBIS, we found a statistically significant positive change in farmers' empowerment levels based on measuring self-efficacy, sense of control, and motivation before and after they used the application. Commercial organizations have since adopted this mobile-based system in India and Sri Lanka to solve agricultural problems, in universities Africa to mitigate hidden hunger, and the Corporative Research Center in Australia to develop digital health applications to manage chronic diseases, which indicates the approach's wide adoptability.

Keywords: Empowerment Framework, Mobile-based Information Systems, Design Science Research, Sri Lankan Farmers, Empowerment Processes.

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1 Introduction

This research project has its origins in an attempt to help farmers in Sri Lanka to avoid overproducing agricultural commodities, a problem that has sometimes led to farmers committing suicide (Senaratna, 2005). Studies in India, Sri Lanka, USA, Canada, England, and Australia have identified farming as one of the most dangerous industries as it is associated with a higher suicide rate than the general population (Behere & Bhise, 2009). Along with the farm environment's physical stressors and hazards, farmers must deal with a regulatory framework and the economic dynamics of managing a farm business. These factors operate in a context of declining trade for agricultural produce, volatile commodity markets, limited availability of off-farm employment, increasingly expensive machinery and production, and the loss of farm or livelihood due to crop failures (Ramesh & Madhavi, 2009). Further, globally, farmers do not have a customary or mandatory retirement age, which means the younger generation must depend on their parents for much longer than usual (Behere & Bhise, 2009). This dependency can lead to tension between the two generations on the farm. The situation described above leaves farmers feeling powerless, trapped, helpless, and they see that their livelihood never improves.

Most farmers in Sri Lanka make decisions about their livelihood activities using their own knowledge and/or advice from their friends, family, or a village middleperson. This information may not be accurate, up to date, or complete (De Silva, Goonetillake, Wikramanayake, & Ginige, 2012; Lokanathan & Kapugama, 2012). Sometimes, many farmers in one area unknowingly grow the same crop, which results in an oversupply and low selling prices. Farmers often borrow money from moneylenders with very high interest rates and sell their harvest to them to settle their loans, which limits their opportunity to obtain better revenue for their harvest and leaves with little money at the end of the farming season.

Ginige et al. (2016) have previously analyzed the problem in detail and found that its root cause lies in the fact that farmers and many other stakeholders in the domain do not receive accurate, up-to-date, complete information in a suitable format. Farmers need published information (quasi static) about crops, pests and diseases, land preparation, growing and harvesting methods. While they can access this information via different channels such as paper, radio, TV, websites, and mobile devices, these channels do not customize information to individual farmers' needs, which limits its usefulness to farmers and affects the decisions and actions they take.

Farmers need actionable information to make informed decisions that can affect their livelihoods (Ginige & Sivagnanasundaram, 2019). Therefore, to help farmers in Sri Lanka avoid overproducing some crops and underproducing others, they need to better coordinate supply and demand. Such coordination requires a mechanism by which farmers report the extent and type of crops they may be growing at the beginning of a new season as actionable information. The new mechanism would then aggregate this information based on location, time, and crop type to derive current production levels for different crops in real time and would then send this aggregated information to farmers who are about to select crops to grow in the new season. Such information would enable farmers to understand what crops other farmers are planning to grow, their total land area of growth and choose a crop that may not lead to overproducing certain crops. This suggested solution provides farmers a choice in choosing what crop to grow and can lead to crop diversification that may minimize the over-production problem.

When deciding on technology to use to develop a solution, we chose a mobile-based solution due to the rapid growth of mobile phone usage in Sri Lanka. Since 2000, mobile penetration has grown rapidly in Sri Lanka. According to ITU (2018), at the end of 2018, Sri Lanka's mobile-cellular telephone subscription rate reached 124 percent of the population. Indeed, the country's cheapest broadband connections cost just under US$6 a month, which makes Internet connectivity affordable (Dialog, 2018b). Therefore, we conceptualized a mobile-based information system (MBIS) to minimize the overproduction problem.

The above conceptualized solution differs to what farmers have previously practiced when making decisions. Therefore, we faced a challenge in how to change their engrained practices. The empowerment process can help people change their behavior (Karapanos, 2015; Tengland, 2012). To establish a change in behavior in farmers, one needs many crop seasons. Therefore, we narrowed down our research further to investigate the factors that influence farmer behavior and how we could develop a mobile-based artefact to facilitate a change in these factors. If we could detect a change in the factors that govern a farmer's macro behaviors in a single crop cycle, we could infer that, over many crop cycles, we could possibly observe a change in how farmers select crops to grow. In turn, that change could lead to crop diversification and, hence, minimize overproduction.

The empowerment construct integrates the perception that people have about personal control, their proactive approaches to life and how they understand the socio-political environment they work in (Zimmerman, 1995). A set of meaningful goals that a person might pursue drives the empowerment process. One needs to understand the nature of such goals and how they differ across people and contexts to facilitate the empowerment process (Cattaneo & Chapman, 2010). In the psychological empowerment literature, empowerment at an individual level of analysis describes the empowering processes where people create or receive opportunities to control their own destiny and influence the decisions that affect their lives. The empowerment at individual level also suggests that the initiative to engage in behaviors to influence outcomes depends on the attributes such as self-efficacy, competence, belief, and perceived control that people have (Knol & Linge, 2009; Strecher, DeVellis, Becker, & Rosenstock, 1986; Zimmerman, 1995).

In 2012, an International Collaborative Research Group with researchers from Sri Lanka, Australia, Italy, and the United States embarked on a project to develop a Mobile Based Information System for farmers in Sri Lanka and explore ways to overcome production problems for vegetables. This was a complex problem with many research challenges. In order to explore ways to realize the conceptual solution in practice, five higher degree students (four doctoral students and one master's student) from Sri Lanka, Australia, and Italy who were members of an international collaborative research group investigated different areas of the overall research problem: 1) agriculture information ecosystem to address the inefficient and almost non-existent information flow model among the stakeholders (De Silva, 2016), 2) user-centered agriculture ontology to reorganize agriculture data to generate context specific information (Walisadeera, 2017), 3) how to enhance ubiquitous computing environments to provide better human-computer interaction in applications (Giovanni, 2015), 4) context-based content aggregation to support informed decision making (Mathai, 2013), and 5) application development to facilitate user empowerment (Ginige, 2017). In this paper, we present research related to the user empowerment subproject in the overall project: how to design, implement, and evaluate a mobile-based information system to empower farmers to make informed decisions to be in control of their livelihood activities, which should result in farmers' changing their crop selection behavior pattern in ways that help to achieve a better match between supply and demand.

This paper proceeds as follows: in Section 2, we provide background information and related literature. In Section 3, we present our research methodology. We selected design science research as a suitable methodology for developing artefacts to solve a problem (Hevner, March, Park, & Ram, 2004). In Section 4, we present a model for a generic empowerment framework for designing mobile-based information system (MBIS). In Section 5, we present our MBIS's design details. In Section 6, we evaluate the MBIS and discuss our findings. We discuss study's results and limitations in sections 7 and 8 respectively. In Section 9, we discuss the current situation of the MBIS and emerging possibilities. In Section 10, we discuss future research possibilities and conclude the paper.

2 Background and Related Literature

In this section, we present background and related literature. First, we review the theories and concepts related to empowerment. Second, we review various mobile-based solutions currently available in the agriculture domain in developing countries, especially in relation to their ability to empower farmers. Third, we present the research gaps in these mobile-based agriculture solutions and the importance of addressing them.

2.1 Empowerment

Researchers across many areas such as psychology, community development, education, social studies, health, and organizations have extensively studied the empowerment concept (Perkins & Zimmerman, 1995; Rappaport, 1987; Zimmerman, 2000; Zimmerman & Rappaport, 1988). Accordingly, empowerment has a different meaning depending on the perspective and sociocultural and political context. As a result, many definitions for empowerment exist. After studying several definitions, we chose Cattaneo and Chapman's (2010, p. 647) definition since it aligns with the context of Sri Lankan farmers and our focus in this study:

> *Empowerment refers to an iterative process in which a person who lacks power individually and in social relationships, sets a personally meaningful goal oriented toward increasing power, acts*

towards that goal, and observes and reflects on the impact of this action, drawing on his/her evolving self-efficacy, knowledge, sense of control and competence related to the goal.

The theory of empowerment includes both empowerment processes and clearly defined outcomes (Bandura, 1982; Zimmerman, 1995). The theory suggests that actions, activities, or structures may be empowering and that the outcome of such processes result in a level of being empowered. Empowerment outcomes result from empowerment processes. Therefore, one needs to evaluate outcomes to provide the necessary feedback to help empowerment processes continually evolve, to study the effect of interventions designed to empower individuals, and to investigate empowerment processes and mechanisms (Zimmerman, 1995).

In studying human motivation, researchers have identified goals as the key contributing factor to long-term wellbeing (Alsop & Heinsohn, 2005; Austin & Vancouver, 1996; Karoly, 1999). Individuals require goals to function each day, but such goals can be trivial and shallow. Meaningful (and often long-term) goals provide order and structure (Emmons, 2003). One needs to identify meaningful goals to designing empowerment processes. Action is driven by meaningful goals, motivated by the value one places in those goals and beliefs one's ability to reach them, informed by relevant knowledge, and carried out using relevant skills (Freire, 2000).

Empowerment processes often involve decision making and accessing information relevant to the decision. Since complex problems usually have many related factors, traditional logical thinking can lead to sequences of ideas that become tangled that one cannot readily recognize their interconnections (Saaty, 1994). Decision making requires relevant, up-to-date, and readily accessible knowledge. In order to fulfill the overall decision-making goal, one may have sub goals that one needs to fulfill.

Researchers increasingly agree that one can analyze empowerment at the individual, organizational, and community levels (Perkins & Zimmerman, 1995). In our research, we analyzed empowerment at the individual level, which researchers have referred to as psychological empowerment (PE) (Zimmerman, 1995; Zimmerman & Rappaport, 1988). Zimmerman (1995) defines psychological empowerment (PE) as having three components: intrapersonal, interaction, and behavioral. The intrapersonal component refers to how people think about themselves and includes domain specific perceived control and self-efficacy, motivation to control, and perceived competence. The interactional component refers to the understanding that people have about their community and related socio-political issues. The behavioral component refers to actions that people directly take to directly influence outcomes.

Many researchers have described empowerment as an iterative process of gaining power with interactions at all levels (Masterson & Owen, 2006; Speer & Hughey, 1995; Wallis, Dukay, & Mellins, 2008). Fundamentally, empowerment constitutes a positive concept that refers only to solutions rather than problems. Further, it typically involves terms such as self-efficacy, control, self-power, self-reliance, independence, and making one's own decisions (Narayan, 2002) and encompasses sense of personal control, which researchers have clearly linked to greater health and wellbeing (Chandola, Kuper, Singh-Manoux, Bartley, & Marmot, 2004; Griffin, Fuhrer, Stansfeld, & Marmot, 2002; Sue, 1978). Research on empowerment has considered perceived sense of control and self-efficacy, motivation, and competence as the empowerment outcomes at the individual level of empowerment. Competence refers to people's ability to do something successfully ("Competence", 1995) and constitutes an outcome that others can objectively and externally assess. In contrast, the other empowerment outcomes, which we describe next, involve subjective internal assessment of the individual. We also look at the concept of choices as it is central to the design of our MBIS for empowerment.

2.1.1 Self-efficacy

Perceived self-efficacy refers to people's beliefs about their capabilities to produce designated levels of performance that influence events that affect their lives (Bandura, 1994). People differ in the areas in which they cultivate their self-efficacy. Self-efficacy beliefs determine how people feel, think, motivate themselves and behave. Such beliefs produce these diverse effects through four major processes; cognitive, motivational, affective, and selection processes (Bandura, 1994). Therefore, people differ in their efficacy levels in a domain. The self-efficacy belief does not refer to a global trait, but a different set of self-beliefs linked to distinct realms of functioning (Bandura, 1997). Therefore, no all-purpose general measure of perceived self-efficacy exists.

2.1.2 Sense of Control

Sense of control refers to people's perceived degree of freedom or discretion in carrying out work activities (Hall, 1986). At its core, self-control involves the perception that one can effectively control one's own life as compared to the belief that one has no power to control one's important life outcomes (Gecas, 1989). It reflects the reality of an individual's experiences, opportunities, and resources (Mirowsky & Ross, 1989). Some concepts related to a sense of control include mastery (Pearlin, Menaghan, Lieberman, & Mullan, 1981), locus of control (Rotter, 1966), self-efficacy (Bandura, 1997), instrumentalism (Wheaton, 1980), and personal autonomy (Deci, Schwartz, Sheinman, & Ryan, 1981).

2.1.3 Motivation

Pinder (1998) defines work motivation as "a set of energetic forces that originates both within as well as beyond an individual's being, to initiate work-related behavior, and to determine its form, direction, intensity and duration" (p. 11). Motivation can be either intrinsic or extrinsic. Intrinsic motivation comes from inside an individual. For example, people may want to learn something because they have interest in it or wants to extend their skills, while others may want to accomplish a goal or task because they feel competent at and enjoy doing it. On the other hand, extrinsic motivation comes from outside an individual. They might be bribed to do something, or they might earn a prize, money, marks, recognition, or other reward.

2.1.4 Relationship between Choice and Empowerment Outcomes

The construct choice relates to empowerment outcomes such as sense of control, motivation, self-efficacy, and competence. Exercising choice has many psychological benefits for individuals. Research across many domains has shown that providing choice increases intrinsic motivation and competence (Deci, & Ryan, 1985, 2000). Tasks have different difficulty levels, and most people choose tasks depending on their self-efficacy beliefs (Bandura, 1977, 1982). For example, an individual may choose a very difficult task because that person believes in their ability (i.e., self-efficacy) to accomplish that task. It also gives them an opportunity to increase their sense of competence (Deci, & Ryan, 1985; Pintrich, Schunk, & Meece, 2002). Choice has the capacity to execute the behaviors one needs to influence empowerment outcomes (Bandura, 1977).

2.2 ICT4D: Mobile-based Information Systems for Agriculture in Developing Countries and Related Technology Development

Information and communication technology for development (ICT4D) is a field of research and practice that joins specialties from computer science, information systems, and development studies. In the last decade, we have seen explosive growth in ICT use in developing countries, much of which we can attribute to mobile phones (Walsham, 2017). The International Telecommunication Union (ITU) estimates that, at the end of 2018, mobile cellular-telephone subscriptions in the world and developing countries reached 107 and 102.8 percent of the population, respectively (ITU, 2018).

Agriculture constitutes a major economic sector in many developing countries, which includes Sri Lanka (27% of the country's total economic sector) (Department of Census and Statistics, 2017), India (55%) (Department of Agriculture, Cooperation, and Farmers Welfare, 2017), and Africa (70%) (AGRA, 2017). The debate on the role of mobile technologies in agriculture forms part of a wider debate on using ICT in economic and social development. To reap the full benefits from the mobile revolution in developing countries, people should have affordable and easy access to mobile devices, mobile internet infrastructure, and mobile applications that help them in their livelihood activities. According to the technology company zMessenger, around 40 percent of Sri Lanka's 14 million mobile subscribers possess a smartphone (Wettasinghe, 2017). In 2018, monthly subscriptions for mobile data packages ran as low as US$6 a month in Sri Lanka (Dialog, 2018a). This data justifies the decision that our international collaborative research Group took to create an information system that people could access using smart devices.

Many projects have successfully enhanced some sections of the farming supply chain and brought economic and social benefits in the developing world. For example, India has many mobile-based information systems: Avaaj Otalo (a service for farmers to access relevant and timely agricultural information over the phone) (Patel et al., 2010), eSagu (an agro-advisory solution to improve productivity) (Reddy & Ankaiah, 2005), and mKrish (an agro-advisory service to address the issues of farmers) (Karale, Mohite, & Jagyasi, 2014). Related to agriculture produce, market information systems in developing countries focus especially on providing market information (Kopicki & Miller, 2008; Kuek, Qiang, Dymond, & Esselaar, 2011; Magesa, Michael, & Ko, 2014; Parikh, Patel, & Schwartzman, 2014). These projects connect farmers and sellers by providing commodity prices and market information using the short message service (SMS) or the Web.

Sri Lanka has seen a handful of mobile-based applications that allow farmers to obtain agriculture market information: Smart Cultivation Partner (Nirojan & Vithana, 2017), 6666 Agri-price Index (HARTI, 2014), and Dialog Trade Net (Dialog, 2010). In Kenya, KACE (Karugu, 2015), DrumNet (Innovations for Poverty Action, 2015) (originally a project of PRIDE AFRICA), and CGIAR (CGIAR, 2014) mobile applications provide market information to farmers and create links between farmers and markets. In Ghana, ESOKO (ESOKO, 2009) and mFarms mobile applications (mFarms, 2013) provide crop production and market information to the farmers. RATIN, another mobile application that provides real-time, relevant, and accurate market information, operates in five Eastern African countries (i.e., Kenya, Uganda, Tanzania, Burundi, and Rwanda) (RATIN, 2015). The Grameen foundation in Kenya has been developing a mobile application to help smallholder maize farmers properly store and manage crops, link to financial institutions to receive financial help against the value of their stored crops, and connect with markets for final sales (Grameen, 2002).

In reviewing the literature, we found that most current agriculture mobile solutions allow farmers to receive information in a passive mode and supply only a small amount of the information they require. These solutions lack an empowerment model to motivate the end user. Li et al. (2012) conducted a project that drew on empowerment theory but did not focus on agriculture or users in developing countries. They proposed an online system that draws on psychological empowerment theory (Zimmerman, 1995) to empower victims of domestic violence through providing tailored information and mutual support. However, they collected no data, and they did not validate the online system.

Though we have not found any other work that has embedded key concepts from the empowerment literature into a framework to ensure products empower their users and has measured the impact on user empowerment after they use a product designed using such a framework, other researchers have studied how ICT can empower disadvantaged groups. Leong, Pan, Newell, and Cui (2016) report how access to e-commerce empowered two remote villages in China and how it led to community-driven development. After data collection, they used empowerment as a lens to interpret the case study data first by identifying critical actors and how they used ICT followed by analyzing how different actors afforded different uses to the same ICT. Leong et al. (2016) found that ICT empowered some individuals more than others and led to several changes: it effected a "new fitness landscape", helped knowledge diffuse quickly, helped roles evolve and diversify, and created a supportive environment. Ghosh, Khuntia, Chawla, and Deng (2014) explored how IT-enabled communication can play a role in shaping patients' psychological empowerment for managing diabetes. They argued that the communication medium between patients and providers influences the former's psychological empowerment (Zimmerman, 1995). Thus, they hypothesized media reinforcement to impact the relationship between self-awareness and life-changing interventions. They tested their conceptual model using archival data that they collected from surveying 78 patients in diabetes-management education programs. The results indicate that rich media enabled by IT can play a significant role in patient empowerment and influence chronic disease management's outcomes.

AbuJarour et al. (2019) examined the refugee crisis and how refugees use information and communication technology (ICT) in different regions across the world to understand how ICT supports their difficult journey to safety, their stay in temporary settlement camps, and their post-settlement inclusion in host countries. They conducted various interviews with Syrian refugees in Berlin, Germany, to collect preliminary insights. Then, they organized panel discussions at two key information systems conferences (ICIS 2016 and ECIS 2017) that involved participants from various countries. The panel discussions revealed seven key research themes: accessibility to information, availability of education and linguistic resources, admissibility to labor markets and entrepreneurship opportunities, communicability with home country, connectedness with local population, interactivity with host government, and volunteer coordination. They discussed how ICT might help to address issues related to each theme, presented research questions relevant to each theme, and illustrated how refugees have employed ICT to address an aspect of each theme. Based on their insights, they discussed theoretical implications and future opportunities for research in the information systems (IS) field, practical implications for different stakeholders interested in refugee integration to consider, and social implications related to refugee crisis that we cannot ignore.

Social media plays an instrumental role in enabling and facilitating social movements. Existing literature focuses on social media's informational role and episodic effect in community activism and provides little insight into the formative role that social media has in social movements. Tye, Leong, Tan, Tan, and Khoo (2018) presented the case of Bersih, a social media-enabled social movement that pushed for electoral reform in Malaysia. The non-partisan community-driven movement exerted public pressure on institutions and gained formal recognition. The authors uncovered the significant role social media plays in empowering citizens by enabling them to facilitate and coordinate collective action towards producing change in their community.

As another example about social media's instrumental role in enabling and facilitating social movements, Mohan, Potnis, and Alter (2013) examined how one can use ICT to increase the scale of microfinance operations to the extremely poor whom banks do not serve. Currently, micro-finance institutions (MFI) physically send MFI agents to reach the extremely poor in remote villages—a costly undertaking. The authors presented three MFI case studies in India that deployed IS to help scale door-step banking and, thus, to reach the poor. By presenting microfinance examples that impact the economic empowerment of the poor, they addressed the dearth of research on using IS to affect social change at the bottom of the pyramid.

In their study, Slavova and Karanasios (2018) demonstrated how the availability of (technical and non-technical) information artefacts among smallholder farmers in Ghana led to information-practice hybridization process. The authors found that information artefacts served to link farmers' activities that followed the smallholder logic with agricultural-development actors' activities that promoted the value-chain logic. Hybridization occurred through farmers using artefacts with different interaction modalities. In terms of conceptualizing change, the authors found that the point at which the two logics become hybridized may be an intermediary point in the long transition from the smallholder toward the value-chain logic.

Dadgar and Joshi (2018) investigated how to design sociotechnical artefacts to empower diabetic patients to better manage their own health. Despite technological advances in healthcare ICTs that improve care and reduce costs, patients often avoid using them. The author focused on value sensitive design to conduct an in-depth interpretive field study to reveal the values that diabetic patients find important. The conceptual model that emerged from the field study explains how these values, which ICT features integrate, afford or constrain patients' abilities to self-manage their activities. This study makes multiple theoretical contributions and has implications for design science researchers, healthcare providers, and policymakers.

Wilson and Diamasbi (2019) focused on user experience (UX) in how users subjectively evaluate digital products, services, and software in the mobile computing domain. Currently available measures can produce only single-score usability measures or cover only a part of the mobile device-software user experience. The researchers added two multifaceted survey instruments to UX researchers' and practitioners' toolkit: the mobile user experience (MUX) instrument and the short-form MUX (sMUX). The authors evaluated MUX's and sMUX's convergent and discriminant validity across multiple combinations of mobile software and mobile devices and proposed that these new usability instruments can improve mobile UX.

Sherif and Jewesimi (2018) examined how recent advances in electronic performance monitoring (EPM) have raised employee concerns regarding invasion of privacy and the erosion of trust. However, using data analytics in EPM promises to improve organizational and employee performance. Aligning an EPM system's design with organizational culture and establishing effective organizational mechanisms to address concerns will positively affect how employees perceive the technology. Based on data the authors collected from two organizations in the US and in Qatar in the oil and gas sector, the authors found organizational efforts to promote EPM's image as an employee-empowering technology and as providing objective feedback to achieve individual and organizational goals.

2.3 Knowledge Gap in Current Mobile-based Agricultural Solutions in Developing Countries

Undoubtedly, many successful agriculture related projects/applications that we discuss above have enhanced some sections of the farming supply chain and produced many economic and social benefits. These projects have focused on one or two stages of a whole farming lifecycle. For example, some agriculture solutions provide farmers information on good cultivation practices or pest and disease management only for the seeding, preparing, and planting stages of a farming cycle. A complete farming cycle can include as many as six stages that have different information needs and activities (De Silva & Ratnadiwakara, 2010). While farmers need to understand current market prices to benefit from that information, they first need to produce a successful crop harvest while minimizing the cost that harvesting it incurs. Thus, when providing information, one should adopt a holistic approach to cater for all information needs of the overall crop cycle. No project we identified explicitly addressed empowerment or how to motivate targeted users to use technology to its full potential. For example, the themes that AbuJarour et al. (2019) identified relate to refugees' meaningful goals, though the authors did not explicitly specify them. Further, based on reviewing the literature, we found a gap and, hence, an opportunity to examine how one can develop mobile-based applications to empower users.

3 Research Methodology

In this research project, we designed, developed, and evaluated a mobile-based artefact to empower farmers. To do so, we selected the design science research methodology (DSR). DSR provides a framework to design innovative artefacts that define ideas, practices, technical capabilities, and products. Further, it assists one in iteratively analyzing, designing, implementing, and evaluating artefacts that involve novel approaches (Hevner et al., 2004).

3.1 Design Science Research Methodology

Though DSR suits efforts to develop artefacts well, our research project had additional characteristics to consider. The agriculture domain has many subdivisions and complex interactions between them. At the beginning of this research, we found it difficult to clearly understand these interactions and how the subdivisions functioned as a whole. Therefore, it seemed the problem we investigated represented a wicked problem with some ill-structured characteristics such as the agriculture domain's complexity, the lack of clearly defined user requirements, and the impact that the many issues of other stakeholders in the agriculture domain had on the farmers (Brooks, 1996; Rittel & Weber, 1984). It became clear that, in this investigation, we needed an adaptive software development approach that could support an iterative learning, implementation, and evaluation process (Highsmith, 2013).

DSR has three cycles: 1) the relevance cycle in which one identifies and represents opportunities and problems in an actual application environment and defines acceptance criteria for the ultimate evaluation of research results, 2) the rigor cycle in which one draws from a vast knowledge base of scientific theories and engineering methods that provide the foundation for rigorous design science research, and 3) the design cycle, the heart of any design science research project, in which one iterates more rapidly between constructing an artefact, evaluating it, and using the subsequent feedback to refine the design further. Researchers can iteratively move around these cycles until they develop a suitable artefact. At the end, they need to validate the iterative research process that they followed against the checklist for design science research (Hevner & Chatterjee, 2010). We provide this validation in Appendix B.

3.2 Creating DSR Subcycles

From research process's perspective, we faced two major challenges:

a) We faced an ill-structured problem with unclear and ill-defined user requirements. Therefore, each investigation had to iterate through several cycles in which we focused on learning the established theory, understanding the problem, designing and building prototypes, validating its functionality, and field testing it to validate its suitability in the environment.

b) There were five higher degree research projects that were carried out in three different geo-locations that shared much of the problem understanding activities and needed to contribute to an integrated artefact at the end. To establish the suitability of the artefact, during intermediate stages and at the end, the artefact had to undergo thorough relevance cycles that involved farmers in Sri Lanka.

To accommodate these specific challenges and better manage and coordinate activities that occurred across the multiple subprojects, we needed to extend the original DSR methodology with DSR subcycles (Ginige, De Silva, Walisadeera, & Ginige, 2018a). As such, we divided each main DSR cycle into two subcycles (see Figure 1). We describe each DSR subcycle and how we implemented them for this research project in Appendix A. The mobile-based information system resulted from several iterations. We used the checklist that Hevner and Chatterjee (2010) suggest to assess the progress of the project (see Appendix B).

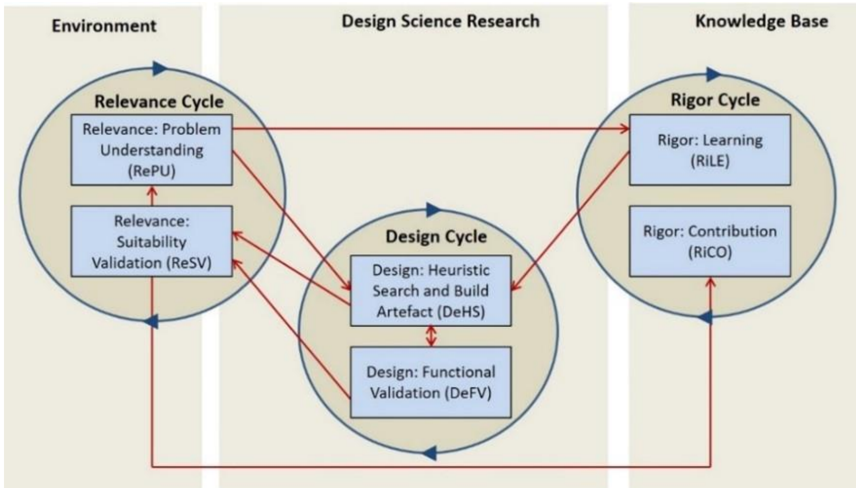

Figure 1. Design Science Research (DSR) Subcycles and Interactions among them (Ginige et al., 2018a)

3.3 Research Questions

The literature survey we carried out in this investigation did not reveal how to develop a mobile-based artefact to empower users. As such, we developed the following overall research question (RQ) for this project:

> **RQ**: How to design, develop, and evaluate a mobile-based application to empower farmers in their livelihood activities?

First, we developed a generic empowerment framework grounded in theory to guide the process of developing a mobile-based artefact to empower users (in this case, farmers). Second, we developed a mobile-based artefact based on the empowerment framework. Third, we developed a mechanism to systematically evaluate whether using mobile-based artefact over a crop cycle had any impact on the elements that govern farmers' behaviors. To address these requirements, we formulated three additional research questions.

> **RQ1**: How can one empower farmers in their livelihood activities?
>
> **RQ2**: How can one develop a suitable mobile-based information system (MBIS) for Sri Lankan farmers based on an empowerment framework?
>
> **RQ3**: How can one evaluate MBIS to measure the impact it had on the farmers?

We address these latter three research questions in Sections 4 to 6.

4 Empowering Farmers in Their Livelihood Activities

In this section, we discuss how one can empower farmers in their livelihood activities (RQ1). The main objective of RQ1 was to determine the elements of the empowerment by studying specific instances of farmer empowerment. When addressing RQ1, we developed three artefacts:

1) A generic empowerment model for users
2) An empowerment model for Sri Lankan farmers, and
3) A generic empowerment framework to create mobile-based artefacts.

In designing these artefacts, we iterated among the DSR cycles relevance (understanding the problem), rigor (learning), and design (heuristic search) several times (see Appendix A).

We investigated several areas: farmers' goals, the opportunities and the obstacles they face in the agriculture environment, how farmers make decisions, and the type of technology they used prior to the mobile artefact we eventually introduced. Since we focused on empowerment, we first focused on understanding the concepts that underpin empowerment theory, on understanding psychological empowerment, and on understanding the key drivers of empowerment. While considering users' goals, empowerment theory's concepts, and our research focus, we then designed a generic empowerment framework on which we could build mobile applications. Next, we customized the generic empowerment framework to create a context-specific empowerment framework for the Sri Lankan farmers that comprised a conceptual empowerment model to represent their goals, empowerment processes. and empowerment outcomes.

4.1 Generic Empowerment Framework

We show the generic empowerment framework in Figure 2. In designing an empowerment framework, one first needs to identify users' meaningful goals (Alsop & Heinsohn, 2005; Freire, 2000). The way people set their meaningful goals depends psychological empowerment's (PE) intrapersonal component (which describes how they think about themselves and domain-specific perceived control, self-efficacy, motivation, perceived competence and mastery they have) and on its interactional component (which describes the way they understand their environment, community and socio-political issues, available resources, and how they can acquire them). PE's intrapersonal and interactional components drive its behavioral component. It is the behavioral component of PE where a person engages in behaviors to exert control in their activities (Zimmerman, 1995).

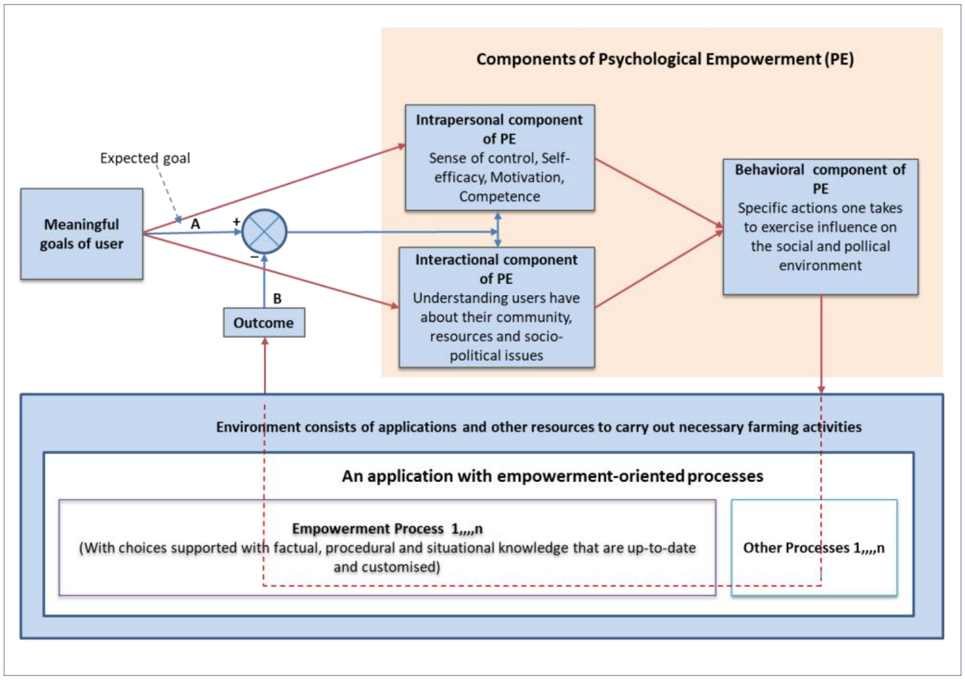

Figure 2. Generic Empowerment Framework

In Figure 2, we show the generic empowerment framework that links users' meaningful goals, PE's components, and the environment in which users reside. When users work in an environment, they use applications and other resources in it to perform their livelihood activities. Since people have varying degrees of PE's intrapersonal, interactional, and behavioral components, they exhibit different behaviors when they use applications and resources in an environment. For example, if users have choices in a given context, they can query, learn, and evaluate them to choose one to exert control in the environment (deCharms, 1983; Deci & Ryan, 1985; Hall, 1986; Zimmerman, 1995). Users also need to develop a critical awareness of resources available to them, how to acquire them, and learn new skills to use the available resources effectively to achieve their meaningful goals (Freire, 2000). Decision making, one important task that users perform, requires relevant, up-to-date, and readily accessible knowledge (Saaty, 1982). Therefore, if applications have processes that support different behaviors to help users achieve meaningful goals, such applications may become more helpful to empower people.

As Figure 2 shows, “A” refers to the initial meaningful goal that a user expects. Depending on the degree to which people exhibit PE’s intrapersonal, interactional, and behavioral components, there will be an outcome (“B”) that may be equal to, greater than, or less than their expected goal (“A”). The difference between “A” and “B” allows users to see a closer relationship between their effort and a sense of how to achieve their meaningful goals (Mechanic, 1991; Zimmerman, 1990). For example, consider the following example with a man named John: if the outcome B matches his original goal A, then it reconfirms that his efforts and behavior enabled him to achieve his goals, and he may even feel confident to achieve a better outcome B in the future. If the outcome B is greater than the original goal A, in addition to seeing the relationship between his efforts and the outcome, he may even feel confident and motivated to learn and use new ideas or become a leader in the community. If the outcome B is less than the original goal A, he may reflect on how to improve his decision-making and problem-solving skills and better understand his socio-political environment and participatory behaviors to achieve a better outcome next time (Balcazar, Seekins, Fawcett, & Hopkins, 1990; Kieffer, 1984; Zimmerman, Israel, Schulz, & Checkoway, 1992; Zimmerman & Rappaport, 1988).

4.2 A Context-specific Empowerment Framework for the Sri Lankan Farmers

We conducted two data-gathering sessions in Sri Lanka in December, 2012, and November, 2013, to derive a context-specific empowerment framework for Sri Lankan farmers based on the generic empowerment framework we developed (see Figure 2).

In December, 2012, we conducted the first data-gathering session at Dambulla and Galewela over two days. Altogether, 32 farmers participated: 18 at Dambulla and 14 at Galewela. We used two questionnaires. In this session, we asked farmers to perform several tasks on their mobile phones such as sending a SMS, making a call, browsing a website, and taking a picture. We observed how they completed these tasks. The first questionnaire had closed-ended questions with multiple answers to capture the farmers’ demographic information, such as their gender, educational level, employment details, land ownership, community involvement, decision-making process, methods they used to access information, and mobile phone and Internet usage. The second questionnaire had both closed-ended questions with multiple responses as answers and open-ended questions. We used the second questionnaire to determine how farmers carried out a cost-benefit analysis in farming, their experience of doing the tasks on mobile phones, how they used technology, and how technology could help them to improve their knowledge, skills, and decision making.

In November, 2013, we conducted an extensive data-gathering session with 50 Sri Lankan farmers at six different locations over five days. The farmers came from locations close to the major cities Dambulla (19), Pollonnaruwa (21), and Galigamuwa (10). We interviewed the farmers with a questionnaire that included semi-structured, open-ended questions to gather additional relevant information. With these questions, we focused on understanding in detail the activities that the farmers conducted in farming, the information they needed to conduct the farming processes, how they received and used this information to make decisions, choices they could make and their autonomy to choose them, their strengths and weaknesses, their beliefs about their competency, and their engagement in the community. Further, we provided farmers an opportunity to use an application on a smartphone and noted their experiencing in using it. The application, a profit calculator, displayed the possible profits when farmers entered the values of expenses and expected revenue. We discuss the 2012 and 2013 data-gathering sessions and the findings we obtained from them in more detail in past conference publications (see De Silva et al., 2012; Ginige & Richards, 2012; Giovanni et al., 2012; Walisadeera, Wikramanayake, & Ginige, 2013). We summarize that work here to provide background information.

We used the insights that we gained from these data-gathering sessions and empowerment theory to develop a context-specific empowerment framework for the Sri Lankan farmers. In Table 1, we show the steps we took to create the empowerment framework. We present each step-in detail in Sections 4.2.1 to 4.2.4.

Table 1. Steps in Creating a Context-specific Empowerment Framework

Step no.	Description
1	Identify and list meaningful goals.
2	Identify and list empowerment and supporting processes and the different types and sources of knowledge that those processes should use.

Table 1. Steps in Creating a Context-specific Empowerment Framework

3	Based on the first and second steps, design a context-specific empowerment model with meaningful goals, empowerment processes, and empowerment outcomes.
4	Identify and list useful and motivating choices in context. Add them in the empowerment processes.

4.2.1 Meaningful Goals for Farmers (Step 1)

People have individual and context-specific goals in life (Cattaneo & Chapman, 2010). Therefore, we spoke to each individual farmer to understand the goals they found meaningful and the goals they could act on based on their situation, beliefs, skills, competencies, and knowledge. From the interviews and survey data we collected in the 2012 and 2013 data-gathering sessions, we found that farmers had the following meaningful goals:

1) To have financial security and feel safe
2) To have easy access to relevant and up-to-date information to make informed decisions
3) To learn new skills and ideas, and
4) To become an active member of the farming community.

4.2.2 Identifying Empowerment Processes and Related Knowledge for those Processes (Step 2)

The 2012 and 2013 data-gathering sessions revealed that the farmers often made uninformed decisions that led to limited success or even failure at the end of a farming cycle due to their using irrelevant, not up-to-date, or incomplete information. To make informed decisions, farmers need:

5) Access to relevant information at multiple stages in the crop cycle
6) Expense information for all stages of a crop cycle
7) Customized information for personalized goals
8) Procedural knowledge that helps them to use the factual knowledge meaningfully, and
9) Different tools to provide factual knowledge and procedural knowledge

When designing our MBIS, we used these insights to assist farmers to make better decisions at various stages of a crop cycle. Farmers noted that they wanted to have financial security and to feel safe. To achieve the best possible revenue at the end of a crop cycle, farmers need to decide which crop to grow at the beginning of a crop cycle. To make this decision, farmers must receive information with the following attributes:

1) Customized information about which crops they can grow on their land, which enables to select crops appropriate to the soil and weather conditions of their farm.
2) Aggregated information with regards to how much of the same crops other farmers in their area have already grown.

The customized and aggregated information assists farmers to make informed decisions about selecting a crop that will grow on their land and, thus, helps them avoid an overproduction situation. Once farmers have selected a crop, they carry out a cost-benefit analysis to decide whether they could feasibly grow it. Each stage of a crop cycle involves several expenses. To carry out an expense calculation, farmers need information such as the quantity and cost of each item in each stage and procedural knowledge such as how to use the factual knowledge to perform expense calculations correctly. For this purpose, they require an expense calculator. The expense calculation provides farmers with the expense of each item, the expense for each stage, and the expense for whole crop cycle. Therefore, providing farmers with a list of crops that they can grow in their farm, information about what other farmers in the area have already decided to grow, and a means to calculate the expense of growing a crop can help them make an informed decision about which crop(s) to grow at the beginning of a crop cycle. Further, such factors would enable farmers to select a financially feasible crop that would not saturate the market and that may produce better revenue at the end of a crop season, which would help them achieve financial security.

After we better understood how farmers make decisions, we identified three empowerment processes and three supporting processes that we needed to implement in the artefact to enable farmers to achieve the meaningful goals we discuss above. In Table 2, we show the empowerment processes, supporting processes, and their representation on a mobile phone as a menu item.

Table 2. Empowerment and Supporting Processes and their Representation on the Mobile Menu

Process type	Process name	Process name in the mobile application's menu
Empowerment	Finding crops to grow	Crop selection
	Calculating expenses	Expense calculator
	Selling the products and services of farmers	My offerings
Supporting	Viewing past expenses	Expense history
	Communication	Discussion forums
	Organizing finances	Micro finance

4.2.3 Context-specific Empowerment Model for Sri Lankan Farmers (Step 3)

We needed an empowerment model to ensure that the MBIS design captured the targeted farmers' empowerment processes and outcomes (Zimmerman, 1995). In this project, we focused on building an application not only to solve a problem while satisfying a set of functional and non-functional requirements but also to empower its users. Particularly in developing countries where communities do not have the same freedom, opportunities, and access to ICT as communities in developed countries do, following a product-centered software-development lifecycle may result in dependencies rather than individual development and community advancement (Sen, 2008). For example, a product could tell farmers what crop to plant—a feature (i.e., functional requirement) that they need. But such a product would not empower farmers when making their own decisions or increase their self-efficacy. Rather than *telling* farmers what to grow, the application should *involve* farmers in selecting a crop by themselves. It can provide them with choices by providing a list of crops that can grow on their farm and help them understand the extent to which other farmers have already grown particular crops and the cost of growing them. Thus, with such an application, farmers can make informed decisions, which can improve their motivation, self-efficacy, and sense of control (Bandura & Schunk, 1981). Furthermore, we needed to develop a context-specific empowerment model to provide a basis to measure changes in farmers' empowerment levels and to evaluate the MBIS designed based on the empowerment framework.

From the information we gathered in the first and second steps, we developed a context-specific empowerment model for Sri Lankan farmers that comprised meaningful goals, empowerment and supporting processes, and empowerment outcomes (see Figure 3). Empowerment processes and any supporting processes should support each meaningful goal to help farmers achieve them. Table 3 shows which processes address each meaningful goal in the MBIS. Empowerment outcomes refer to specific measurement operations (whether quantitative or qualitative in nature) that one may use to study the effects of interventions designed to empower participants (Zimmerman, 1995). Since we focused on developing an artefact to facilitate behavior change via empowerment in our project, we considered factors such as competence, sense of control, self-efficacy and motivation as empowerment outcomes as they can influence farmers' behavior.

Table 3. Meaningful Goals and Empowerment Processes

Meaningful goal	Related processes
To have financial security and feel safe	Finding crops to grow (empowerment) Calculating expenses (empowerment) Viewing past expenses (supporting) Selling products/services of farmers (empowerment) Organizing finance (supporting)
To have easy access to relevant, up-to-date information	Finding crops to grow (empowerment) Calculating expenses (empowerment) Selling products/services of farmers (empowerment)

Table 3. Meaningful Goals and Empowerment Processes

To learn new skills and ideas	Finding crops to grow (empowerment) Calculating expenses (empowerment) Viewing past expenses (supporting) Communication (supporting)
To become an active member in the farming community	Selling products/services of farmers (empowerment), Communication (supporting)

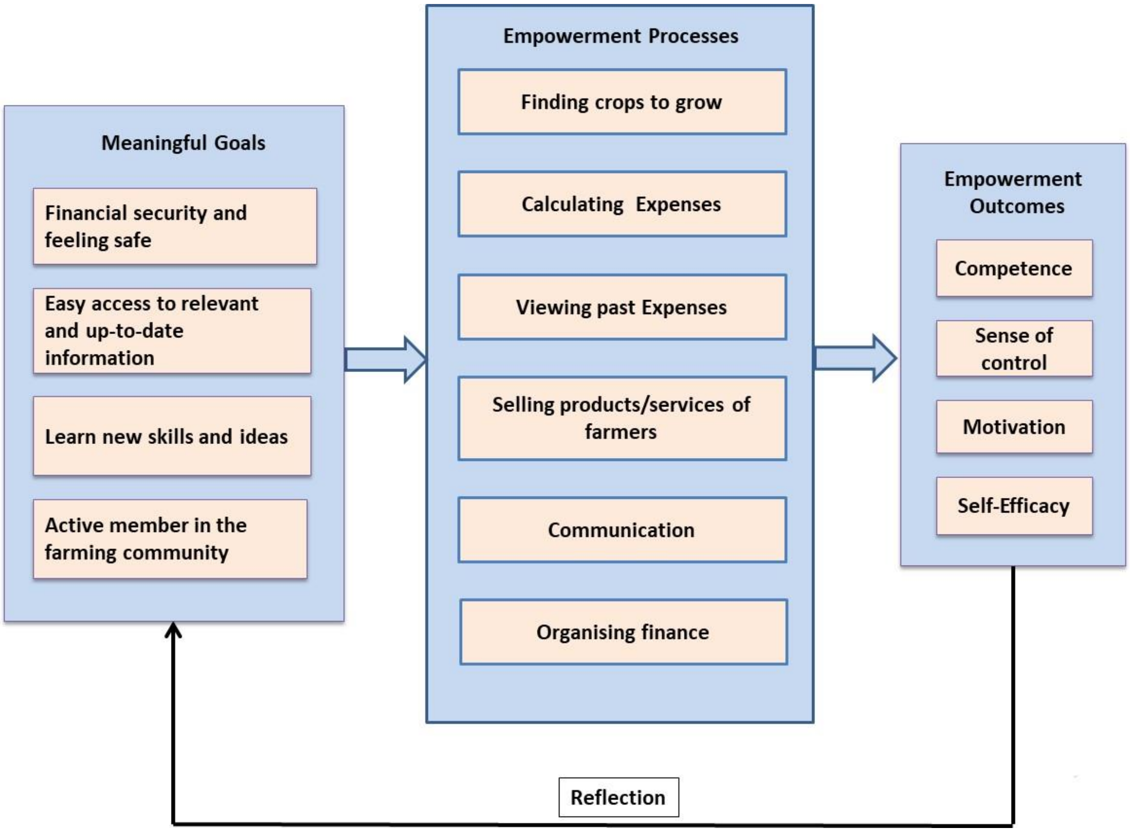

Figure 3. Empowerment Model for the Sri Lankan Farmers

4.2.4 Identifying Useful and Motivating Choices, in Context, in the Empowerment Processes (Step 4)

The 2012 and 2013 data-gathering sessions revealed that farmers did not have many choices when making decisions. When individuals have a choice, they may feel a sense of autonomy, control, or empowerment (Iyengar & Lepper, 1999). Many research studies have supported that embedding choices in processes can lead to informed decision making and increased the following PE intrapersonal components: sense of control (Halaby & Weakliem, 1989; Hall, 1986), motivation (Deci & Ryan, 2000, 1985; deCharms, 1968; Deci, Speigel, Ryan, Koestner, & Kaufman, 1982; Schulz & Hanusa, 1978), self-efficacy (Bandura 1982; Bandura and Schunk 1981; Bandura 1977), and competence (Deci & Ryan, 1985, 2000). Therefore, we embedded choice when designing the MBIS's empowering processes to support farmers' varied behaviors. When the MBIS offered a choice, farmers could select the option that they found personally feasible, evaluate it, and make informed decisions to achieve their meaningful goals.

5 Design Details of MBIS and Empowerment-oriented Processes

In this section, we discuss how we addressed research question 2 (RQ2): how can one develop a suitable mobile-based information system (MBIS) for Sri Lankan farmers based on an empowerment framework.

To do so, we customized the generic empowerment framework we developed in the context of Sri Lankan farmers (see Section 4). In our design activities, we iterated through relevance (understanding the problem) of DSR, rigor (learning) of DSR, and design (heuristic search) of DSR several times (Appendix A). The result of addressing RQ2 was the overall design and implementation of the artefact: MBIS. Figure 4 illustrates the context data flow diagram of the MBIS. It interacts with four external entities: farmer, supplier, agriculture ontology, and geographical information system.

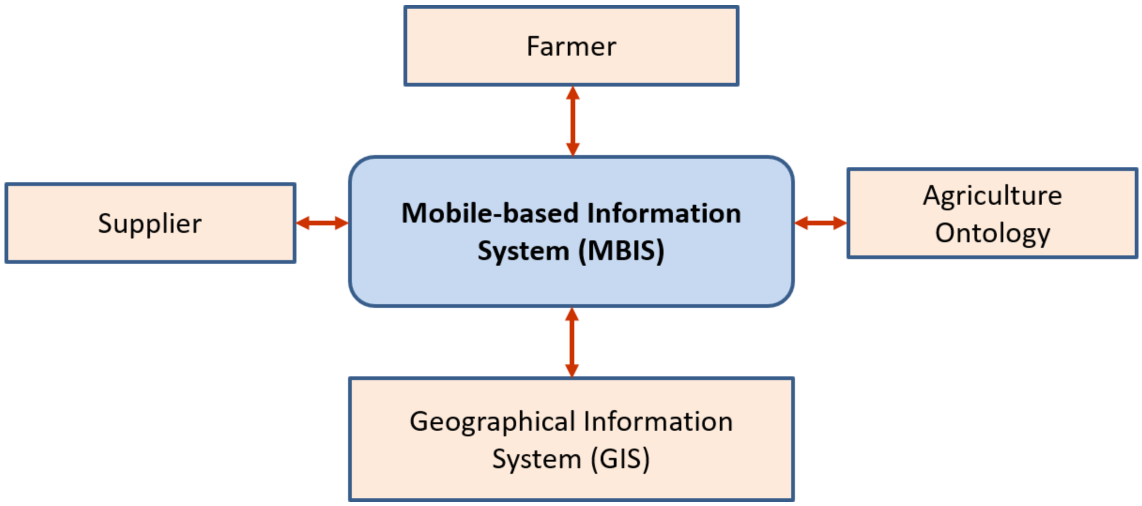

Figure 4. MBIS's Context Data-flow Diagram

5.1 High-level Design of MBIS

We show the MBIS's high-level architecture for Sri Lankan farmers in Figure 5. It has three major areas: a mobile front-end, an application server that comprises the farmer application and back-end data management, and an agriculture ontology. For farmers, the mobile front-end constitutes the interface between them and the MBIS. Farmers interact with the application via the tools on the mobile front-end. We briefly describe all the associated MBIS processes and tools in Table 4.

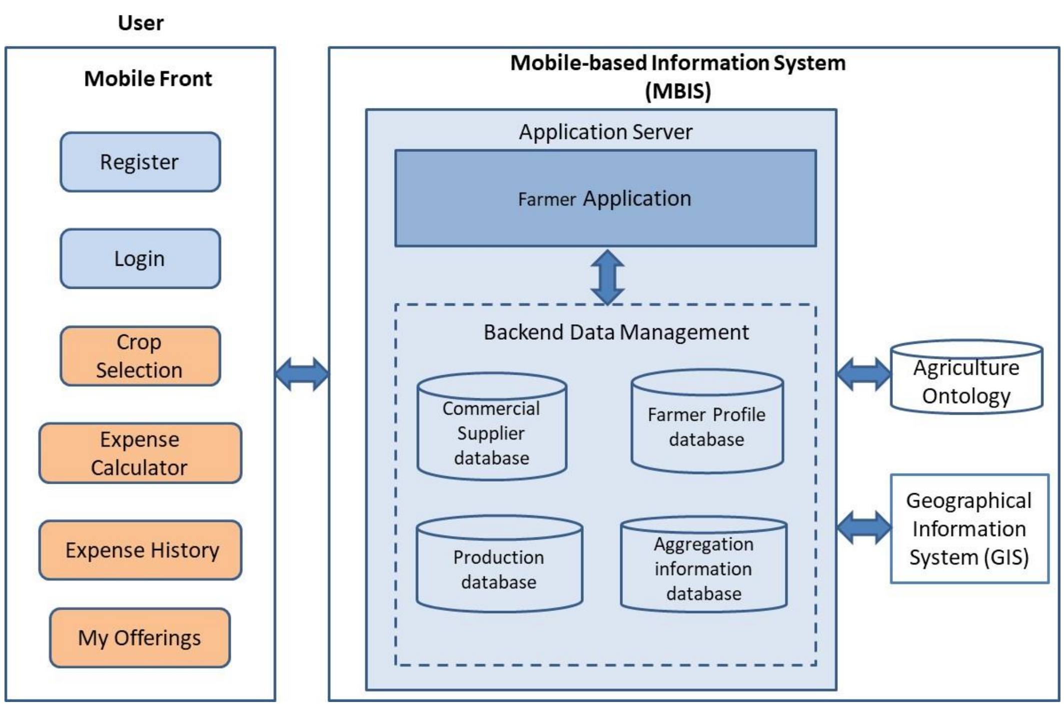

Figure 5. High-level MBIS Architecture

Table 4. Description of Overall Functions of Mobile-based Information System (MBIS)

Overall function of MBIS mobile	Description
Register (general)	A new farmer must first register with the application using the farmer's Sri Lankan national ID number, mobile number, and name. The application sends an SMS with a pin number to the farmer's mobile phone to establish that it is a valid mobile number. The farmer registration process allocates each farmer a farmer_ID and stores it in the farmer profile database. This registration process identifies farmers and provides required customized information in other processes in the application.
Login (general)	Registered farmers need to use their phone number and pin number to login to the application in their future visits, and the farmer_ID will be used to manage data and activities associated with a farmer.
Crop selection and expense calculator (empowerment processes)	Crop selection is one of the most important processes in the whole crop cycle. It is where farmers make the critical decision on which crop/s to grow. In the crop-selection process, a farmer first needs to either register a new farm or select an already registered farm. Once a farmer selects a farm, the farmer receives a list of crops that grow in a selected farm, creates a short-list of crops, performs necessary expense calculations via expense calculator, and, finally, decides on which crop/s to grow. Each farm can have a lengthy list of crops that can be grown. Rather than performing expense calculations for all the crops in the list, farmers can choose few crops to perform expense calculations. This shorter list of crops makes the decision making efficient.
Expense history (supporting process)	This process keeps expense calculations of selected crops of previous seasons. It facilitates a farmer to select a crop. Whenever a farmer makes a final decision on which crop/s to grow, farmer can view the expense history for comparison purposes when making informed decisions in a new season.
My offerings (empowerment process)	Farmers often face some difficulty finding a market space when competing with established sellers. The my offering process provides farmers with an additional avenue to enter a market space through the MBIS.
Geographical information system (GIS) (back-end)	Once a new farm is registered or a registered farm is selected, the geographical information system (GIS) identifies the agro-zone of the farm and sends it to the agriculture ontological knowledge base. The agriculture ontological knowledge base then sends the farmer a list of crops that can be grown in the selected farm.
Agriculture ontological knowledge base (back-end)	The agriculture ontological knowledge base contains all the details related to crop knowledge. For example, the agriculture ontology contains the detailed characteristics of a crop, agro ecological zones where a crop grows, how the crops are grown, common pests and diseases. In addition, it has details of fertilizer, pesticides, and other chemicals and the amounts that need to be applied in various stages of a crop cycle.
Production database (back-end)	The production database stores data that a farmer enters, such as the size of a farm and the extent of a crop that is grown. In addition, it stores expense calculations that a farmer carries out.
Commercial supplier database (back-end)	This database has the details of suppliers who provide seeds, fertilizer, pesticide, chemicals, packaging, machines, transport, other services and related expense details. When a farmer selects an item to buy, the supplier database provides the farmer with a list of suppliers who sells that item along with details such as sale price and contact information.
Aggregation information database	This database contains aggregated knowledge derived from data captured through farmer activities.
Micro-finance and discussion forums (supporting processes)	To be implemented in the future.

We show the empowerment model for the Sri Lankan farmers with processes (empowerment and supporting), tools, and data management in Figure 6. We designed this model by combining the empowerment model for Sri Lankan farmers (see Figure 3) with the MBIS system architecture (see Figure 5).

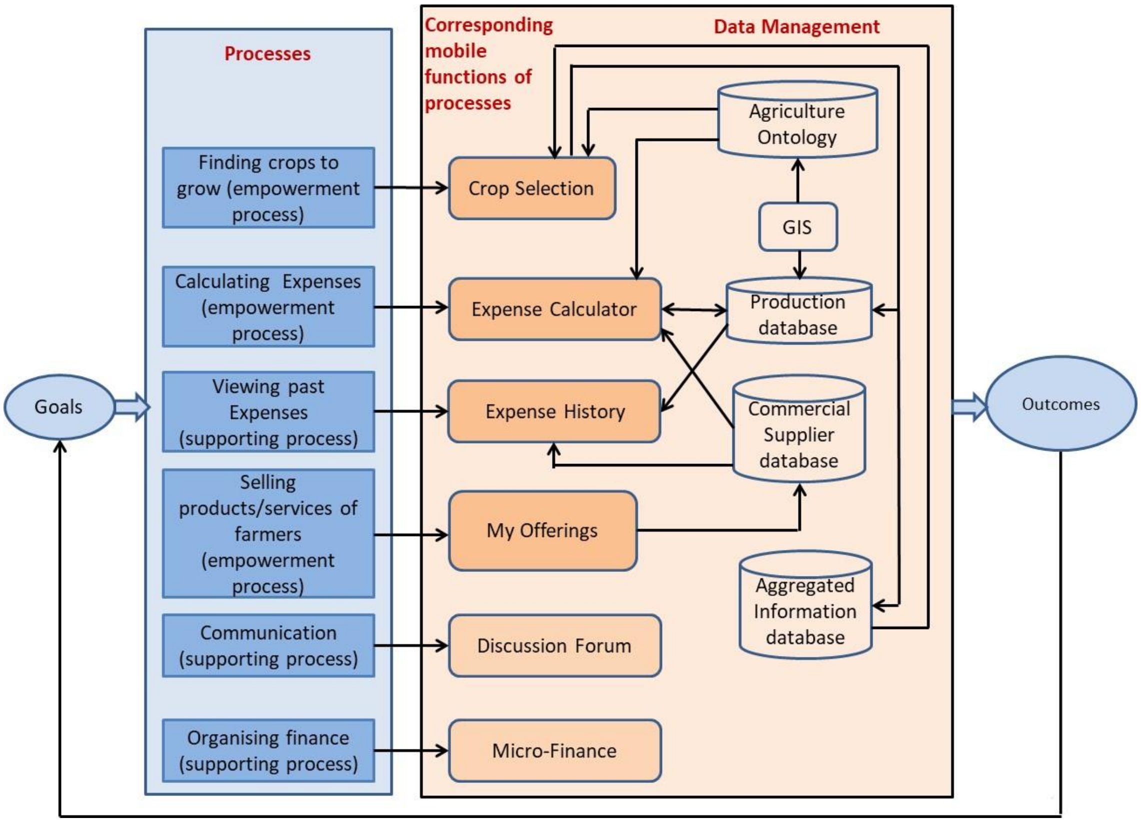

Figure 6. Empowerment Model for Sri Lankan Farmers with Processes (Empowerment and Supporting), their Corresponding Mobile Functions, and Data Management

5.2 Design Details of Empowerment-oriented Processes: The "Finding Crops to Grow" Empowerment Process

The MBIS design includes three empowerment processes (see Table 2). We designed these processes to support informed decision making by providing relevant choices wherever applicable with appropriate knowledge to implement the choices that farmers selected. In this section, we discuss how we designed one empowerment process (the most important process in the whole crop cycle): "finding crops to grow".

We show the relevant mobile screens in the finding crops to grow (FCG) empowerment process in Figure 7. When registered farmers log in (screen A in Figure 7), they can select "crop selection" from the main menu of the mobile (screen B in Figure 7). Farmers can select either a registered farm (screen C in Figure 7) or register a new farm using an address or the map (screens D or E in Figure 7). When farmers select a registered farm, the application provides 1) a list of crops that they can grow in the farm and 2) information about the extent to which other farmers in the area have selected these crops to grow or already grown them (screen F in Figure 7). This screen indicates this latter information with color (red for high growth, green for medium growth, yellow for low growth, and white for no growth). When farmers select a crop this list, the application will display its varieties (screen G in Figure 7) and details about a selected variety (screen H in Figure 7).

In Figure 8, we show details about all the processes in the FCG empowerment process. When farmers select a registered farm, the application shows all the crops that grows in the selected farm and their current production levels (C1 in Figure 8). Farmers can then select a crop and the application will provide information about it (K1 in Figure 8). From this knowledge, farmers can decide whether to add this crop to a "short list" of crops that they may want to grow (D1 in Figure 8). Farmers will repeat this process if they want to add more crops to the short list (D2 in Figure 8). At the end of the FCG empowerment process, farmer scan create a short list of crops to grow in the new farming season.

Figure 7. Mobile User Interfaces for the "Finding Crops to Grow" Empowerment Process

After farmers have created a short list of crops that they may want to grow, the application then navigates to the next empowerment process, calculating expenses. In summary, an expense calculator tool that performs the expense calculations associated with each stage of a selected crop's crop cycle supports this empowerment process. The expense calculator links to a list of suppliers and their sale prices and contact details. Both these empowerment processes provide farmers with several choices and relevant knowledge to compare their choices and evaluate them to make informed decisions.

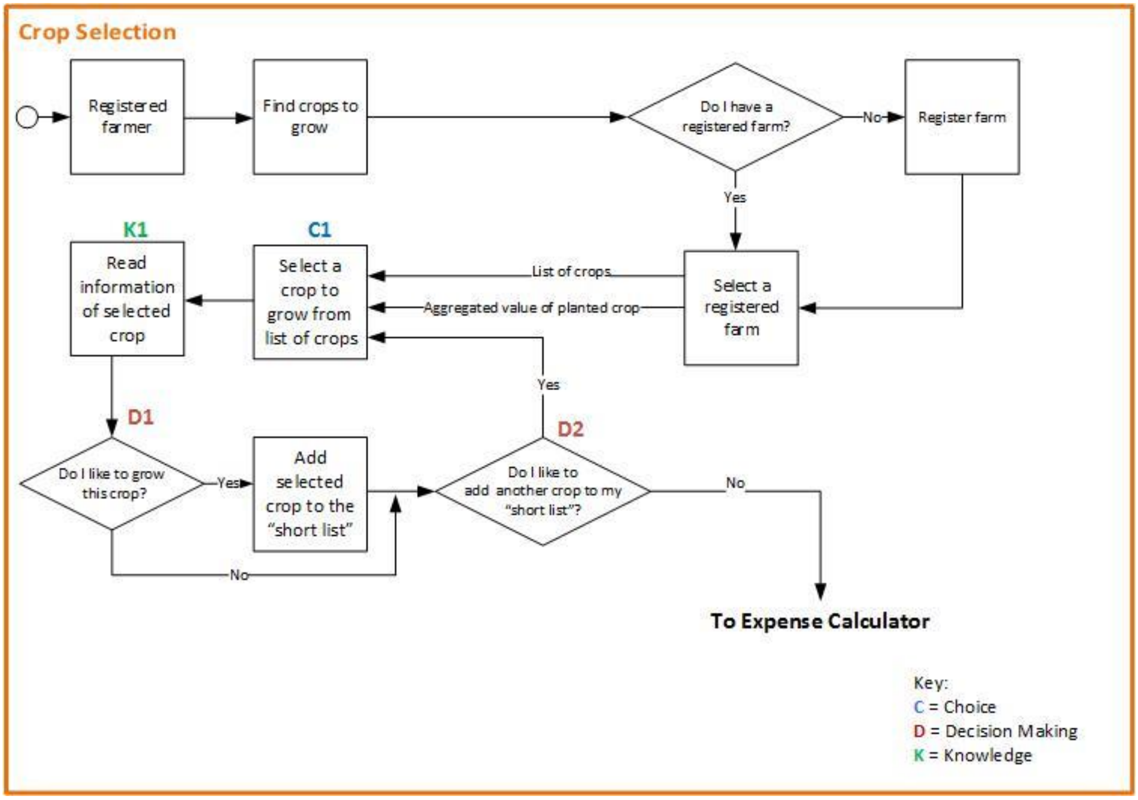

Figure 8. Implementing Choice and Knowledge in the "Finding Crops to Grow" Empowerment Process

6 The Impact the Mobile-based Information System had on Sri Lankan Farmers

In this section, we discuss how we evaluated our MBIS to measure the impact it had on the farmers (RQ3). To address this question, we created one artefact to measure farmers' empowerment outcomes. This process involved the rigor (learning), design (heuristic search), and relevance (suitability validation) DSR cycles (see Appendix A). In Sections 6.1 to 6.3.4, we discuss how we designed instruments to measure empowerment outcomes (self-efficacy, sense of control, and motivation), discuss how we deployed the MBIS to collect data, present the results and how we analyzed them, and evaluate the impact that the MBIS had on the farmers.

6.1 Designing Instruments to Measure Empowerment Outcomes

First, we reviewed the literature to understand available instruments to measure the empowerment outcomes. Second, we designed an instrument that we tailored to measure the Sri Lankan farmers' empowerment. In this study, we focused on sense of control, motivation, self-efficacy, and competence as the essential empowerment outcomes. The final instrument contained seven questions on sense of control, nine questions on motivation, and 22 questions on self-efficacy that we took or adapted from existing validated instruments. We computed an average value of each empowerment outcome for each farmer before we used the MBIS (pre data), and after we used the MBIS (post data). We did not measure competence because we could not observe and measure farmers' competence in the field.

6.1.1 Self-Efficacy

In this study, we employed Bandura's (2006) guide for constructing self-efficacy to develop an instrument to measure self-efficacy. For measurement purposes, we created self-efficacy items to reflect the farming activities of the Sri Lankan farming domain. W(Bandura, 2006)(Bandura, 2006)(Bandura, 2006)(Bandura, 2006)(Bandura, 2006)(Bandura, 2006)hen designing self-efficacy items, we included routine farming activities such as whether a farmer can apply various fertilizers to a crop correctly and potentially more challenging tasks such as whether a farmer can exercise influence to change a decision that government authorities have made. Farmers recorded their efficacy belief on carrying out farming activities on a 100-point scale that had 10-unit intervals from “cannot do” (0) to “moderately certain can do” (50) to “highly certain can do” (100) (Bandura, 2006).

6.1.2 Sense of Control

Ryff’s psychological wellbeing (RPWB) scale, a widely used theoretical model of psychological wellbeing, encompasses six distinct dimensions of wellness: autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance (Ryff & Keyes, 1995; Springer & Hauser, 2006). For our study, we did not require all the dimensions because we focused on understanding sense of control in the context of the autonomy dimension as it relates to managing farmers’ livelihood. RPWB includes 11 items under autonomy, and, from them, we selected seven items as appropriate for the farmers in the farming domain. We recorded the responses on a Likert scale with the anchors agree strongly (1), agree moderately (2), agree slightly (3), neither agree nor disagree (4), disagree slightly (5), disagree moderately (6), and disagree strongly (7).

6.1.3 Motivation

To measure farmers’ motivation, we used the work extrinsic and intrinsic motivation scale (WEIMS)—a measure of work motivation grounded in self-determination theory (Deci & Ryan, 2000). WEIMS includes 18-item measures of work motivation (Tremblay, Blanchard, Taylor, Pelletier, & Villeneuve, 2009). We selected nine out of 18 items that pertained to the farmers in the farming domain. For example, we deemed the statement “I don’t know why, we are provided with unrealistic working conditions” not applicable and, thus, did not include it. We coded the responses on a Likert scale with the anchors agree strongly (1), agree moderately (2), agree slightly (3), neither agree nor disagree (4), disagree slightly (5), disagree moderately (6), and disagree strongly (7).

6.2 Deploying the Mobile-based Information System (MBIS) to Collect Data in 2015

In March, 2015, at the beginning of a farming cycle, we deployed the MBIS in Sri Lanka with 30 farmers who had also participated in the field trial in November, 2013. We refer to this data as pre data since we collected it before we introduced the MBIS to the farmers’ environment. In September, 2015, six months after farmers had been using the MBIS, we collected data again (post data). In both the March and September trials, five researchers from the Australian and Sri Lankan research groups spent four days in Dambulla and Pollonnaruwa. Colleagues at the University of Colombo, Sri Lanka, organized the farmers to attend the field trials at the designated agricultural offices. We conducted this field trial in the farmers’ native language: Sinhala. We gave each farmer a copy of the questionnaire to record their responses and allocated a member from the research team to work with them individually. The research member provided clarity about any question that the farmers did not completely understand.

In the March field trial, farmers carried out two activities. First, they filled in the questionnaire. Afterwards, we deployed the MBIS by providing each farmer a smartphone with the application installed on it. This application comes in three languages: Sinhala, Tamil, and English (three commonly used languages in Sri Lanka). Second, farmers carried out many activities to learn the functions on the smartphone. Most of the farmers had seen smartphones before but they did not own one. Therefore, we spent some time with each farmer to explain and demonstrate how the application worked. It gave them an opportunity to familiarize themselves with the application and ask questions. We provided farmers with a user manual written in Sinhala that explained how to use the application. We also introduced farmers to a technical officer whom they could contact if they had any issues with the application or Internet connectivity. We used a server to log the farmers’ activities on the application. When we had not recorded any activity recorded on the server for several days, the technical officer contacted the farmers to help them to resolve their issues. The University of Colombo provided these smartphones free of charge to the farmers and paid their telecommunication bills during that period with the understanding that the farmers would use MBIS in the new farming season.

In the September field trial, we met the farmers again and collected the data from them using the same questionnaire. In this post MBIS data-collection phase, 28 out of the 30 original farmers participated. We provide the demographics of the 30 farmers in Appendix C.

6.3 Results

We calculated the mean values of the responses for the three empowerment outcomes (sense of control, motivation, and self-efficacy) for each farmer based on the March data that we collected immediately prior to deploying the MBIS and before they had experienced it and on the September data that we collected six months after they had used the MBIS (i.e., pre and post data, respectively). We show these values in Appendix C. Using these results, we conducted the following analyses to determine the impact that the MBIS had on the farmers.

6.3.1 Analysis One: Did Farmers' Empowerment Outcomes Change due to the MBIS?

In this analysis, we first performed a dependent t-test to compare the mean values of pre and post values of sense of control (before: $M = 5.19$, $SD = .47$, $t(27) = 6.078$, $p < .0001$; after: $M = 5.75$, $SD = .50787$), motivation (before: $M = 5.43$, $SD = .55$, $t(27) = 2.73$, $p < .05$; after: $M = 5.69$, $SD = .53$), and self-efficacy (before: $M = 60.84$, $SD = 10.88$, $t(27) = 7.93$, $p < .0001$; after: $M = 76.35$, $SD = 8.18$). The results indicate that values for all three empowerment outcomes were higher after we introduced the MBIS with the farmers.

Second, we performed a dependent t-test to compare the mean values of self-efficacy data that we collected in November 2013 (before we introduced the MBIS), and March 2015 (after we introduced the MBIS). The results show no statistically significant difference in the scores (March 2015: $M = 60.84$, $SD = 10.88$) and self-efficacy (November 2013: $M = 59.66$, $SD = 9.43$), $t(27) = 0.16$, $p =.156$).

6.3.2 Analysis Two: How much did Each Farmer's Empowerment Outcomes Relatively Change due to the MBIS?

In this analysis, we examined the relative change in individual farmers' empowerment outcomes due to the MBIS we introduced. We calculated the relative change in each farmer's empowerment outcomes using the following formula: relative change in empowerment outcome = (mean value of post data – mean value of pre data) / (mean value of pre data). We show the relative change in individual farmers' empowerment outcomes in Table 5.

Table 5. Relative Changes of Farmers' Empowerment Outcomes

Farmer ID (FID)	Sense of control (%)	Motivation (%)	Self-efficacy (%)
1	15%	13%	41%
2	31%	28%	63%
3	27%	2%	10%
4	22%	8%	35%
5	-5%	17%	20%
6	26%	-8%	9%
7	6%	16%	27%
8	11%	17%	17%
9	0%	2%	47%
10	3%	-11%	6%
11	21%	24%	9%
12	31%	-2%	43%
13	14%	14%	5%
14	8%	11%	19%
15	6%	-9%	7%
16	12%	-2%	20%
17	14%	10%	55%
18	3%	7%	-2%
19	0%	-9%	19%

Table 5. Relative Changes of Farmers' Empowerment Outcomes

20	-5%	11%	46%
21	3%	7%	24%
22	19%	2%	16%
23	8%	-4%	22%
24	7%	-4%	4%
25	5%	14%	97%
26	13%	-2%	29%
27	15%	0%	34%
28	9%	2%	78%

Most changes were positive (i.e., post data value exceeded pre data value). We highlight negative relative changes (i.e., post data value did not exceed pre data value). Farmer 18 reported a two percent decline in self-efficacy, two farmers (5 and 20) reported a five percent reduction in sense of control, and almost one-third of farmers reported lower motivation.

6.3.3 Analysis Three: Was there a Significant Relationship between Empowerment Outcomes?

In this analysis, we performed bivariate-Pearson correlation to determine whether we could find any significant linear relationship between empowerment outcomes in pre and post values of self-efficacy, sense of control, and motivation. The results in Table 6 for the pre data show no significant correlations.

Table 6. Bivariate Pearson Correlation Results (March 2015, pre data N = 28)

		Sense of control (pre)	Motivation (pre)	Self-efficacy (pre)
Sense of control (pre)	Pearson correlation	1	.032	.228
	Sig. (1-tailed)		.435	.122
Motivation (pre)	Pearson correlation	.032	1	.085
	Sig. (1-tailed)	.435		.334
Self-efficacy (pre)	Pearson correlation	.228	.085	1
	Sig. (1-tailed)	.122	.334	

Next, we performed the bivariate-Pearson correlation on the post data. We found a significant correlation among the empowerment outcomes.

1) Sense of control (post) was significantly correlated with motivation (post) ($r = 0.504$, $p < 0.01$, $n = 28$)
2) Sense of control (post) was significantly correlated with self-efficacy (post) ($r = 0.434$, $p < 0.05$, $n = 28$), and
3) Motivation (post) was significantly correlated with self-efficacy (post) ($r = 0.326$, $p < 0.05$, $n = 28$).

6.3.4 Analysis Four: Was there a Relationship between the Farmers' Application Use and their Empowerment Levels?

In this analysis, we investigated whether we could identify a relationship between farmers' application-usage patterns and their empowerment outcomes. Once a farmer logged on to the application, they could navigate to many different areas. For this investigation, we chose the activities in Table 7 that help farmers to make informed decisions.

We computed several log activities of each farmer: the total number of all logged activities that each farmer performed by adding of their log entries for all activities as follows: total number of all logged activities of each farmer = activity 1 + activity 2 + ….. + activity n.

Some of the main processes in the application, such as selecting a crop or selling a product/service, comprise multiple activities. We computed the total number of logs for selecting a crop process as follows: total number of logs on selecting a crop = crop List selection + crop list view + short list addition + short list removal + short list extent

Using the MBIS application, farmers can sell a product or provide a service. In this process, farmers carry out several activities in the application. We computed the total number of logs on selling a product/service as: total number of logs on selling a product/service = my offerings stage selection + my offerings addition + my offerings deletion.

Table 7. Names and Descriptions of the Application's Activities

Activity name	Activity description
Login	Login to the application
My information	View, edit and save farmer's personal information
Main menu	View main menu and select a sub menu
Crop list selection	Select a crop from the selection
Crop list view	View crops in a list
Short list addition	Add crop to the short list
Short list removal	Remove a crop from the short list
Short list extent	Add the area of the farm to the short list
My offering stage selection	Select a stage to sell a product
My offering addition	Add a product to sell
My offering deletion	Delete a product to sell
Expense history selection	Calculate expense and view history of previous expenses
Viewing products price list	View the product lists of suppliers

We show the descriptive statistics of these logs in Appendix C. To investigate whether application usage correlated to an improvement in empowerment outcomes, we performed Pearson correlation for empowerment outcomes (post) with the logs of "login to the application" and logs of "all activities". We show the re-organized results of the Pearson Correlation analysis below:

1) Motivation (post) was significantly correlated with logs of "login to the application" process ($r = .34$, $n = 28$, $p < .05$)
2) Self-efficacy (post) was significantly correlated with logs of "login to the application" process ($r = .437$, $n = 28$, $p < .01$)
3) Logs of "login to the application" process was significantly correlated with logs of "all activities" ($r = .87$, $n = 28$, $p < .01$)
4) Motivation (post) was significantly correlated with logs of "all activities" ($r = .389$, $n=28$, $p < .05$)

7 Discussion

Prior to our deploying the MBIS in in Sri Lanka in March, 2015, no other mobile applications existed that featured empowerment processes to support informed decision making in farming activities. Farmers receive information they need from scattered and disparate sources: agriculture officers, leaflets, booklets, family and friends, radio, and television. In some instances, they receive information late and in an incorrect or irrelevant format. During the March to September, 2015, farming season, farmers used the MBIS to make informed decisions to carry out their farming activities. As we show in Section 6, the several analyses we performed to evaluate the effectiveness of the MBIS show the impact it had on the farmers.

7.1 Change of Empowerment Outcomes of the Farmers

The results from a dependent t-test we performed in the first analysis indicate that the mean values of all three empowerment outcomes increased after farmers have used the MBIS. The results from the second analysis show a relative positive change in sense of control (11%), motivation (6%), and self-efficacy

(25%) for the group. Often, the environment we live in introduces new ideas and support that lead to improvements in our lives similar to the notion of natural resolution rates for many health conditions. Similarly, the improvement in the farmers' empowerment outcomes between March and September 2015, may have arisen due to a natural improvement process rather than the MBIS. For example, the farmers could have matured and learnt from experience or been exposed to new agriculture mobile applications, agriculture TV programs, or a subsidized fertilizer program. To understand whether the changes resulted from their naturally improving or whether they arose from the MBIS, we compared the self-efficacy values from November 2013, and March 2015. As we deployed the MBIS in only March 2015, it did not exist in the environment 16-months prior to that. From conducting a dependent t-test on self-efficacy data during this period, we found no statistically significant difference between November 2013, and March 2015, self-efficacy data, which indicates that, even if the environment included any other technology, a new TV program, or a subsidized fertilizer program, it did not affect the farmers' self-efficacy levels. The lack of significant change in the self-efficacy values in the 16 months prior to our deploying the MBIS provides further evidence that the MBIS contributed to the increase in the empowerment outcomes, particularly for the self-efficacy outcome.

Out of the three empowerment outcomes that we measured, self-efficacy data showed the highest positive relative change (25%) in the group). Except for Farmer 18, all other farmers in the group reported a positive change in their self-efficacy outcome. People have varying levels of self-efficacy that they derive from prior experience such as their ability, attitude, perception, or social support (Bandura, 1982; Schunk, 1995). We designed the MBIS to provide farmers with choices in activities they do, evaluate the impact that their choices have on the outcome, and then make informed decisions. Therefore, it seems that the MBIS has helped them to believe that they can make informed decisions after evaluating the choices available to them. Their experience of using the MBIS may have increased their belief that they can organize and execute activities that affect their livelihood. In the second analysis, we found that 57 percent of the farmers (1, 2, 3, 4, 7, 8, 9, 11, 13, 14, 17, 21, 22, 25, 27, and 28) had a positive change in all three empowerment outcomes. These farmers' high self-efficacy levels may have helped them to feel and sustain motivated and in control even in light of adverse conditions and uncertain outcomes (Corno & Mandinach, 1983; Pintrich & Schunk, 1995). These farmers may have had an intrinsic desire to change (Pinder, 1998). We found that 43 percent of the farmers (6, 10, 12, 15, 16, 19, 23, 24, and 26) had a positive change in two empowerment outcomes and a negative change in one empowerment outcome (mostly in motivation) (Table 5).

Farmers 5 and 20 reported a five percent decrease in their sense of control. However, their motivation and self-efficacy values increased. Though they both had high level of self-belief and motivation, they may have felt that they did not have the freedom, opportunity, or resources to do what they needed to and, hence, reported a decline in sense of control values (Mirowsky & Ross, 1989). The two percent decline in farmer 18's self-efficacy level may indicate that he did not believe that technology could provide him answers for his livelihood activities that much (Bandura, 1994). Further, 32 percent of the farmers had a negative change in motivation, but they all reported positive change in self-efficacy. Though the farmers had positive self-efficacy levels, it does not necessarily mean that they had motivation to pursue a particular goal (Gallagher, 2012). This group of farmers may require extrinsic motivation (Porter, Bigley, & Steers, 2003). We have begun investigating this possibility as to how all the stakeholders in an agriculture value chain can benefit via incentive motivators such as a reduction in purchase price of buying fertilizer and how we could implement such motivators in our application.

7.2 Correlation among Empowerment Outcomes: Self-Efficacy, Motivation, and Sense of Control

From our third analysis, we can further see the impact that the MBIS had on the farmers. While the March data lacked any correlation among the empowerment outcomes (see Table 6), the September data showed a significant correlation among empowerment outcomes: between self-efficacy and sense of control ($r = .434$, $n = 28$, $p < 0.05$), between self-efficacy and motivation ($r = .326$, $n = 28$, $p < 0.05$), and between sense of control and motivation ($r = .504$, $n = 28$, $p < 0.01$). These results concur with the growing evidence about how these empowerment attributes influence each other to change farmers' empowerment levels (Bandura, 1982; Cohen-Mansfield, Marx, & Guralnik, 2003; Porter et al., 2003; Schunk, 1989).

7.3 Relationship between the Farmers' Application Usage and their Empowerment Outcomes

From our fourth analysis (see Appendix C), we found large variances in the log data perhaps because the statistics represent a cohort of farmers who had different levels of self-belief, prior experiences, motivation, and ability to use technology (Bandura, 1982). With regards to using the MBIS, farmers should have the self-belief that it may help their farming or some curiosity to investigate what this new application can do. They show this intention by an action: logging on to the application.

To better understand our log data, we further analyzed it for specific activities that each farmer performed in the application. In Figure 9, we show the logs of the farmers in "login to the application" and "all activities". The median value of "login to the application" was 50.5 (Appendix C). In Figure 9, we further show that 50 percent of the farmers (5, 6, 10, 12, 15, 16, 18, 19, 20, 22, 23, 24, 25, and 26) had logs for "login to the application" below the median level. To understand whether any relationship between farmers with low usage logs and the empowerment outcomes existed, we analyzed these farmers' empowerment outcome. Except for the farmers 22 and 25, all the other farmers (i.e., 5, 6, 10, 12, 15, 16, 18, 10, 12, 24, and 26) recorded at least one negative empowerment outcome (see Table 5).

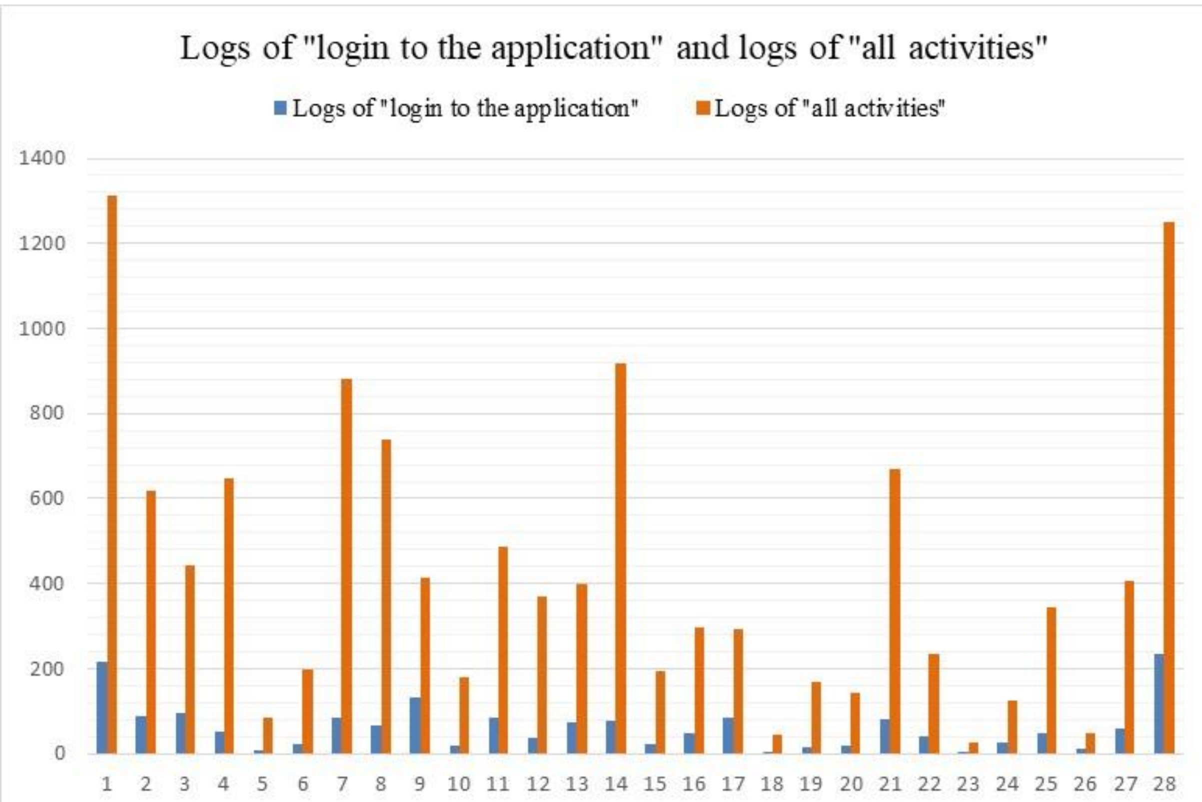

Figure 9. Logs of "Login to the Application" and "All Activities"

After farmers log into the application, they can either stop or continue to navigate to other activities. To investigate what farmers did after they logged on to the application, we analyzed the logs of "all activities". The median value of the logs of "all activities" was 357 (Appendix C). Farmers 5, 6, 10, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, and 26 recorded a log for "all activities" below the median value. Except for one farmer (17), all the farmers who recorded a log for "all activities" below the median value also recorded at least one negative empowerment outcome. This comparison between empowerment outcomes and the logs of "login to application" and "all activities" provides a coarse relationship between the two. It indicates that the level of self-belief, motivation and ability that a person has affects the behavior of that person in different situations, such as using technology in this case (Bandura, 1986).

The statistical analyses that we carried out in the fourth analysis confirmed the above results. In this fourth analysis, we found significant correlations between empowerment outcomes and the logs. In this study, farmers had to use the application we developed to perform activities that could help them to make informed decisions in their farming. Empowerment outcomes such as motivation (post) and self-efficacy (post) both showed a significant correlation to the logs of "login application" process. After logging in to the application, a highly motivated farmer may explore other areas of the application to do more activities. We found as much in the results with a higher correlation factor between motivation (post) and logs of "all activities" than that of motivation (post) and the logs of "login application" process.

7.4 Steps Taken to Check the Quality of the Data We Collected

Our study included a low number of participants. Therefore, we took several steps to ensure we collected high-quality data. We collected demographic data and the technology usage data of the farmers in all four data collections to obtain current data. When analyzing the technology-usage data, we could see how farmers slowly migrated from featured phones towards the smartphones and their interest in using different features on the phones to carry out daily activities. We used such observations when we designed different functions in the MBIS. In developing questions to collect the data related to motivation, self-efficacy, and sense of control, we used already published instruments. We did not use all the questions in these instruments but selected the questions that reflect the Sri Lankan farming domain and Sri Lankan farmers. For example, when creating a set of questions for agriculture planning self-efficacy, we included the activities that Sri Lankan farmers perform in their domain. By doing so, we obtained the most relevant data for our investigation. The total number of participants in our data collections varied, but we always had a common group of 30 farmers in all four data collections, which added to the quality and consistency of the data we collected.

We performed Cronbach's alpha tests on pre and post data for sense of control, self-efficacy, and motivation to measure the internal consistency of the data groups. The results (see Table 8) show a reasonable internal consistency in all data groups. In addition, the results from the third analysis (see Section 7.2) show a significant change in empowerment outcomes after we deployed the MBIS with the farmers but not between other data-gathering periods, which provides cross validation and further supports the quality of the data we collected in this investigation.

Table 8. Cronbach's Alpha Values for Data Groups

Empowerment outcome	Post	Pre
Sense of control	.639	.606
Motivation	.747	.654
Self-efficacy	.878	.883

We also considered cultural sensitivity an important factor in capturing quality data. In the Sri Lankan culture, people do not typically express their feelings and thoughts publicly. They often keep these thoughts to themselves. They will comfortably answer a question such as "For what purposes do you use your mobile?". However, they will often be uncomfortable when the nature of the question concerns their inner thoughts and feelings, such as "I have confidence in my opinions even if they are contrary to the general consensus". Since most of the sense of control and motivation questions we asked concerned their inner thoughts and feelings, they had difficulty understanding and responding to some at the beginning. In such instances, we asked farmers to describe how they understood the question and, if necessary, more clearly and simply explained the question. We informed them that they did not have to explain their responses to the researcher and that they could use the Likert scale to record their response. That made them comfortable when providing their responses. As the sample size was small, each response was valuable.

We used English to create questionnaires for our data-collection processes and conducted sessions with farmers in Sinhala, their native language. Therefore, we translated the questionnaires to Sinhala language with the help from a language translator. When translating the questions, we took extreme care to make sure that the questions still reflected the correct meaning after the translation. Further, in all data-collection processes, we allocated one researcher who could converse in Sinhala language to one farmer. As such, farmers could ask questions freely to obtain clarity and provide their own responses in private.

7.5 Potential Hawthorne Effect

We investigated whether the results we obtained in our study may have had some bias due to the Hawthorne effect. It refers to when subjects in an experimental study attempt to change or improve their behavior simply because it is being observed (Wickstrom & Bendix, 2000). During our investigation between 2012 and 2015, we met the farmers on four occasions. We summarize the activities we conducted and the approximate time we spent on each farmer in those four occasions below:

1) First data-collection period: December 2012, with 32 farmers. Farmers answered a questionnaire. We familiarized them with an application on their mobile phone to calculate profit at the end of harvesting. On average, we spent one-and-a-half hours with each farmer.
2) Second data-collection period: December 2013, with 50 farmers. Farmers answered a questionnaire. We interviewed farmers to gather details. We recorded the interviews with permission. On average, we spent two hours with each farmer.
3) Third data-collection period: March 2015, with 30 farmers. Farmers answered a questionnaire (pre-MBIS data collection). We deployed the MBIS with the farmers *after* we collected the pre-MBIS data. On average, we spent two hours with each farmer
4) Fourth data-collection period: September 2015, with 30 farmers. Farmers answered a questionnaire (post-MBIS data collection). We also conducted an open-ended discussion with each farmer. On average, we spent one-and-a-half hours with each farmer.

In both the first and second data-collection periods, we focused on understanding how farmers performed their farming, how they made decisions, and how they used technology in detail. In the third data-collection period, we first collected pre-MBIS data and then deployed the MBIS by giving each farmer a smartphone with the MBIS installed on it. Doing so avoided the positive bias towards pre-MBIS data due to their excitement about receiving a smartphone. They spent next six months using the MBIS without researchers or any other person observing them. Therefore, when we collected the post-MBIS data six months later, we believe they largely reflected their empowerment levels at the time and that the Hawthorne effect did not overly affect the results.

8 Limitations

We describe various strategies in previous sections that we designed to ensure we collected quality data and minimize potential biases. Nevertheless, the fact that we included only 30 farmers in our two field trials in 2015 represents a research limitation. Most of these farmers had also participated in the data-collection activities in December 2012 (32 farmers), and December 2013 (50 farmers). For each trial, farmers had to travel from their villages to the designated places to meet the research team for one-and-a-half to two-and-a-half hours. Given the added burden to participate and that we did not provide incentives, we considered a sample size of 30 farmers for this research reasonable and meaningful. Various logistical issues such as access, timing, and funding constraints also limited the extent to which we could collect data and, thus, how much data we collected. We had to organize access to participants through the agricultural officers, and it involved traveling to remote areas in Sri Lanka. We also needed to conduct the field trials at appropriate times in the farming cycle. Each field trial had significant monetary costs involved to cover the international and local travel and accommodation required.

9 Current Situation of MBIS and Emerging Possibilities

Since developing the mobile-based information system based on the empowerment framework that we discuss in this paper, many other developments have occurred. The MBIS that we developed for Sri Lanka, called *Govi Nena* (“farmer knowledge” in Sinhala), now has links to the digital agribusiness ecosystem. We also began trialing it in several districts in Sri Lanka. Recently, the researchers in Sri Lanka have successfully secured a large grant from the World Bank to commercialize the *Govi Nena* application. A major agribusiness organization in Sri Lanka has begun conducting a proof-of-concept (PoC) trial with potato farmers in Nuwara Eliya district in the second half of 2019. In addition, the largest agriculture research institute in Sri Lanka has started a major research project to investigate how to manage pest and disease outbreaks using the *Govi Nena* application (Ginige & Sivagnanasundaram, 2019). The MBIS we developed for the Indian farmers, called *Gyan Kisan* (“farmer knowledge” in Hindi), also connects to a digital agribusiness ecosystem, and we have begun trialing it in Telangana state with conventional farmers and in Karnataka state with organic farmers.

In early 2018, researchers conducted a small-scale field trial in South Africa using a modified prototype of the mobile-based information system. This project focused on exploring ways to minimize “hidden hunger” by empowering affected farmers to explore ways to improve the diversity and quality of their diet and identify the crops that they can grow in their geographical farm locations (Ginige, Javadi, Calheiros, & Hendriks, 2018b). This project has now received funding to trial the African version in Kenya, Nigeria, and Malawi. Researchers conducted similar field trials in Fiji and Timor in January 2019.

Due to the generic nature of the empowerment framework we developed (see Figure 2), researchers have used it to develop mobile-based information systems in the agriculture domain in various countries, such as India, South Africa, Kenya, Nigeria, Malawi, Fiji, and Timor. Further, researchers have used this approach to create mobile-based applications in other domains as well. For example, in Australia, researchers have used the mobile-based information system to create a digital knowledge ecosystem in the health domain to help patients better manage diabetes (Mathai, Ginige, Srinivasan, & Girosi, 2017). It captures patients' current life situation, such as their exercise, food, and emotional habits each day using a mobile application and sensor devices. The application collects and aggregates this information before providing it to their care providers, which allows the providers to understand what advice patients have successfully followed and what advice they need to modify. The care provider can set up modified advice as protocols through the system. The system then uses the protocols based on the context to generate the daily actions that patients need to perform.

10 Conclusions and Future Research Directions

In this paper, we present a method for developing a mobile-based information system (MBIS) based on an empowerment framework using the example of an application to empower Sri Lankan farmers. We designed the empowerment framework based on psychological empowerment, a construct that incorporates the people's perceptions and actions in their social context that lead to changes in their behavior. An important element of this framework involves creating empowerment processes to help farmers achieve meaningful goals. Farmers act on these processes depending on their competence, sense of control, motivation, and self-efficacy levels. In addition, we embedded different choices in the empowerment processes that we supported with the relevant knowledge. The concept of choice has strong links to empowerment outcomes such as self-efficacy, sense of control, motivation, competence, and so on. Therefore, exercising choice in applications has many psychological benefits for individuals and has the capacity to execute the behaviors needed to influence the empowerment outcomes.

Based on this framework, we designed a MBIS and deployed it among farmers in Sri Lanka to provide access to real-time, accurate, actionable information that they could use to make informed decisions related to their livelihood activities. Our results about the impact that the MBIS had on the farmers show a statistically significant positive change in their empowerment levels based on measuring their self-efficacy, sense of control, and motivation before and after they used the application. Thus, the results suggest that the MBIS we designed with empowerment in mind helped farmers to change their behavior. Therefore, over many crop cycles, we could observe a consistent change in the way farmers select crops to grow. In turn, such change could lead to crop diversification and, hence, minimize crop overproduction.

Commercial organizations in India and Sri Lanka have since adopted our MBIS and will roll it out to more than 20,000 farmers by 2020. In Australia, Digital CRC Australia has used this empowerment framework to develop digital health applications to help patients manage chronic diseases. The emerging diverse applications for this framework show that one can use it to develop a wide range of mobile-based applications that empower users.

In the research we present in this paper, we focused on developing mobile-based applications to empower individual users. Any domain has several stakeholders who have their own meaningful goals that they would like to achieve. As such, researchers could conduct further research to examine how to empower the individual stakeholders in a domain and their overall impact on the domain. Due to the generic nature of the empowerment framework that we present in this paper, researchers can use it to conduct research in different domains and at the community, state, or country levels to determine their influence on the framework's elements and validity. The motivation to develop and evaluate MBIS goes beyond improving Sri Lankan farmers' livelihood. We hope that this work will impact not just farmers and not just Sri Lanka but other nations and people who, in the future, will benefit from applications that researchers, designers, and developers design explicitly with the empowerment in mind and using the design concepts we offer in this paper.

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Appendix A: Creating DSR Subcycles

We faced complex issues and challenges in the agriculture domain. Therefore, members of the international collaborative research group investigated different areas of the overall research problem, such as information flow among stake holders, agriculture data repository, human-computer interaction, and user empowerment. We can divide the activities in each DSR cycle into two subcycles. In this complex project, each subcycle did not happen at the same time or the location. Therefore, we needed to clearly identify each subcycle.

The research team divided the relevance cycle into two subcycles: "relevance: understanding the problem" and "relevance: suitability validation" (see Table A1). In the understanding the problem subcycle, the team clearly identified the problem, opportunities, and obstacles that existed in the agriculture domain. When team members designed and tested a solution for an immediate goal, they validated its suitability in suitability validation subcycle. This process was iterative.

Table A1. Relevance Cycle Subcycles

Relevance cycle	Relevance: understanding the problem
	Relevance: suitability validation

The research team divided the design cycle into two subcycles: "design: heuristic search" and "design: functional validation" (see Table A2). In the heuristic search subcycle, when the team members identified a good design for an immediate goal, they designed and implemented it. In this subcycle, the research team applied various heuristic search methods to design a good artefact. In the functional validation subcycle, the research team evaluated the artefact's functional validity. The research team iterated many times between these two subcycles to confirm the artefact's functional validity and to ensure it lacked errors.

Table A2. Design Cycle Subcycles

Design cycle	Design: heuristic search
	Design: functional validation

The research team split the rigor cycle into "rigor: learning" and "rigor: contribution" subcycles (see Table A3). The team learned through the literature review process by referring to the existing artefacts, foundations, and methodologies in the knowledgebase in the learning subcycle. The team contributed all new knowledge gained back to the knowledgebase in the contribution subcycle. We show the interactions among these subcycles in Figure A1.

Table A3. Rigor Cycle Subcycles

Rigor cycle	Rigor: learning
	Rigor: contribution

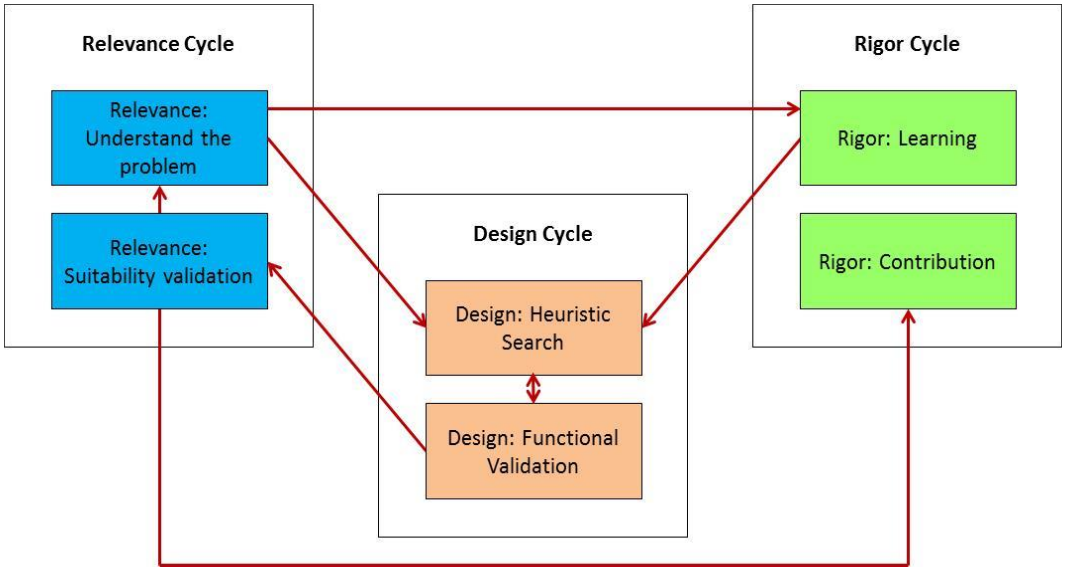

Figure A1. Interactions Among DSR Subcycles

Appendix B: DSR Check List

We used the check list that Hevner and Chatterjee (2010) suggest to assess the progress of our design science research project.

Table B1. DSR Checklist

Check list item	Response
What is the research question (design requirements)?	How to develop a mobile-based application to empower Sri Lankan farmers in their livelihood activities?
What is the artefact? How is the artefact represented?	We created the following artefacts: Artefact 1: a generic empowerment model for users Artefact 2: an empowerment model for Sri Lankan farmers Artefact 3: A generic empowerment framework to create mobile-based artefacts Artefact 4: mobile-based information system for Sri Lankan farmers (MBIS) Artefact 5: instruments to measure empowerment outcomes
What design processes (search heuristics) will be used to build the artefact?	Artefact 1 (a generic empowerment model for users): we used inductive reasoning to apply the facts identified in empowerment theory literature to develop a generic empowerment model for users Artefact 2 (an empowerment model for Sri Lankan farmers): we used the meaningful goals, empowerment processes, and empowerment outcomes identified in 2012 and 2013 data collections to Artefact 1 to develop an empowerment model for Sri Lankan farmers Artefact 3 (a generic empowerment framework to create mobile-based artefacts): we applied different types of knowledge and meaningful choices identified in 2012 and 2013 data collections to Artefact 1 to support informed decision making and provide interaction among empowerment processes Artefact 4 (mobile-based information system for Sri Lankan farmers (MBIS): we integrated Artefact 2 and Artefact 3 to develop the MBIS that can provide customization for each farmer. Each farmer receives a list of crops that grows in farmer’s land, freedom to choose a crop based on current production, perform expense calculation for the selected crop, and select a supplier that provides agriculture input requirements, for informed decision making. Artefact 5 (instruments to measure empowerment outcomes): we applied Inductive reasoning to similar instruments found in Literature to create instruments to measure empowerment outcomes

Table B1. DSR Checklist

How are the artefact and the design processes grounded by the knowledge base? What, if any, theories support the artefact design and the design process?	We grounded the design process of developing the artefacts in the empowerment theory, the psychology literature, and iterative participatory development.
What evaluations are performed during the internal design cycles? What design improvements are identified during each design cycle?	We developed Artefact 4 (mobile-based information system for Sri Lankan farmers (MBIS) by integrating Artefacts 2 and 3. Artefact 1 was generic, and Artefact 2 was a specific instant of Artefact 1. Artefact 4 was the final objective of this research, and we evaluated it Using artefact 5.
How is the artefact introduced into the application environment and how is it field tested? What metrics are used to demonstrate artefact utility and improvement over previous artefacts?	We introduced Artefact 4 (mobile-based information system for Sri Lankan farmers (MBIS) to the farmers as an application installed on a smart phone. Each farmer was provided a smart phone with the application on it in a field trail conducted in March 2015. In this field trial, we collected the data to measure farmers' empowerment levels (pre-MBIS) via questionnaires. We advised the farmers to use the application whenever they wished until September 2015. During this period, no researchers existed in the farmers' environment to observe how they used the application. Farmers had access to a technical officer to resolve any related technology issues such as login or connectivity issues. In September 2015, we conducted another field test using the same questionnaires to collect data to measure the farmers' empowerment level (post-MBIS). We used the pre-MBIS data, post-MBIS data, and the server logs on the application's usage to evaluate impact the MBIS had on farmers' empowerment level.
What new knowledge is added to the knowledge base and in what form (e.g., peer-reviewed literature, meta-artefacts, new theory, new method)?	We added the new knowledge we gained to the knowledge base via journal publishing and peer-reviewed conferences and proceedings. We reference most such works in this paper.
Has the research question been satisfactorily addressed?	We satisfactorily addressed the research question.

Appendix C: Results

Table C1. Farmer Demographics in 2015

		March 2015, pre data (N = 30)		September 2015, post data (N = 28)	
		N	**%**	**N**	**%**
Gender	Male	29	97	27	96
	Female	1	3	1	4
Marital status	Married	27	90	25	89
	Single	3	10	3	11
Education	Up to primary	1	3	1	4
	Up to O/L	22	73	20	71
	Up to A/L	6	21	6	21
	University graduate	1	3	1	4
Ownership of land	Owned	23	77	22	76
	On lease	5	17	4	14
	No comment	2	6	2	7
Employment status	Self employed	26	87	24	86
	Permanent contract	4	13	4	14

Table C2. Pre and Post Mean Values of Empowerment Outcomes for Each Farmer

Farmer ID	Sense of control (pre) (scale 1-7)*	Sense of control (post) (scale 1-7)*	Motivation (pre) (scale 1-7)*	Motivation (post) (scale 1-7)*	Self-efficacy (pre) (scale 0-100)#	Self-efficacy (post) (scale 0-100)#
1	5.86	6.71	5.89	6.67	60.91	85.91
2	4.57	6.00	4.44	5.67	48.64	79.09
3	4.71	6.00	6.11	6.22	70.00	77.27
4	5.14	6.29	5.67	6.11	54.55	73.64
5	6.00	5.71	5.22	6.11	60.45	72.73
6	4.43	5.57	5.78	5.33	54.55	59.55
7	5.00	5.29	5.56	6.44	62.73	79.55
8	5.43	6.00	4.56	5.33	59.55	69.55
9	5.57	5.57	4.67	4.78	61.36	90.00
10	5.57	5.71	6.11	5.44	61.36	65.00
11	5.57	6.71	4.56	5.67	84.55	92.27
12	5.14	6.71	6.22	6.11	54.09	77.27
13	5.29	6.00	5.67	6.44	76.36	80.00
14	5.14	5.57	5.11	5.67	63.64	75.45
15	5.14	5.43	5.89	5.33	73.18	78.18
16	4.86	5.43	5.67	5.56	65.00	78.18
17	5.29	6.00	5.78	6.33	53.64	83.18
18	4.71	4.86	4.56	4.89	63.64	62.27
19	5.71	5.71	5.22	4.78	60.91	72.73
20	5.86	5.57	4.89	5.44	43.64	63.64
21	4.71	4.86	4.78	5.11	63.18	78.64
22	4.57	5.43	5.78	5.89	65.91	76.36
23	5.29	5.71	5.44	5.22	61.36	75.00
24	6.14	6.57	6.22	6.00	86.36	90.00
25	5.29	5.57	5.56	6.33	41.82	82.27
26	4.57	5.14	5.22	5.11	60.00	77.27
27	4.86	5.57	5.78	5.78	49.99	65.91
28	4.86	5.29	5.67	5.78	43.18	76.82

* 1 = disagree strongly, 2 = disagree moderately, 3 = disagree slightly, 4 = neither agree nor disagree, 5 = agree slightly, 6 = agree moderately, 7 = agree strongly; # 0 = cannot do, 50 = moderately certain can do, 100 = highly certain can do.

Analysis One: Checking Farmers' Empowerment Outcomes for Normality

To test normality of data, we computed skewness and kurtosis z-values and conducted Shapiro-Wilk tests. These tests indicated that the data did not follow a normal distribution. Therefore, we performed a non-parametric statistical hypothesis test, the Wilcoxon signed-rank test, to determine whether a significant difference between the mean values of the data we collected existed. We show the median, standard deviation, and Z scores in Table 7. The significant difference between the pre and post data revealed that our intervention had a significant effect ($p < 0.05$) for sense of control ($Z = -4.160$, $p < 0.0001$, $r = -0.7864$), motivation ($Z = -2.374$, $p < 0.0001$, $r = -0.4488$), and self-efficacy ($Z = -4.601$, $p < 0.0001$, $r = -0.86975$). Since the tests for normality only failed in a subset of our measures (i.e., for sense of control (post) and motivation (pre)), we decided to check our results using a standard parametric statistical test.

Table C3 shows that skewness and kurtosis z-values for the self-efficacy values for November 2013, and March 2015, followed a normal distribution. Table C3 shows that the p-value of the Shapiro-Wilk normality test exceeded .05 for self-efficacy in both November 2013, and March 2015. Therefore, we concluded that the data followed a normal distribution.

Table C3. Skewness and Kurtosis z-values Test

	Self-efficacy (November 2013)	Self-efficacy (March 2015)
N valid	28	28
Missing	0	0
Skewness	-.109	448
Std. Error of skewness	.441	.441
Kurtosis	-.263	.582
Std. error of kurtosis	.858	.858

Table C4. The Shapiro-Wilk Test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Self-efficacy (March, 2015)	.149	28	.115	.946	28	.158
Self-efficacy (November 2013)	.063	28	.200*	.982	28	.898

Analysis Four: The Descriptive Statistics of the Logs

Table C5. Statistics of the Logs

	Logs of “login to the application” process	Logs of “selecting a crop” process	Logs of “selling a crop” process	Logs of “all activities”
N valid	28	28	28	28
Mean	62.857	76.571	19.250	425.893
Median	50.500	38.000	6.000	357.000
Mode	3.0[a]	9.0[a]	.0[a]	26.0[a]
Std. deviation	56.6809	94.3525	27.9293	344.8128
Minimum	3.0	.0	.0	26.0
Maximum	236.0	351.0	101.0	1313.0
Multiple modes exist. We show the smallest value.				

About the Authors

Ginige, Tamara is an IT Consultant at CreditAI Pte Ltd, Singapore. She has been working in the agriculture domain in the areas of information systems design, predictive modelling and data analytics, and mobile and web application development. She completed her PhD at Macquarie University, Australia in 2017. Her PhD was "An empowerment Framework for developing mobile-based applications: Empowering Sri Lankan Farmers in their livelihood activities". Previously she has worked as an academic at Australian Catholic University (1998-2018) and at University of Technology, Sydney (1991-1997). Her current interests are to design technological solutions in agriculture value chains to empower users, design AI/ML-based dynamic credit scoring systems to assess the creditworthiness of farmers and data analytics.

Richards, Deborah is a Professor in the Department of Computing at Macquarie University. Following 20 years in the ICT industry during which she completed a BBus (Comp and MIS) and MAppSc (InfoStudies), she completed a PhD in artificial intelligence on the reuse of knowledge at the University of New South Wales, Australia and joined academia in 1999. While she continues to work on solutions to assist decision-making and knowledge acquisition, for the past decade, her focus has been on ethical intelligent systems, agent technologies and virtual worlds that empower users to take control of their learning, problem-solving, decision-making and behaviors.

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