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An Empowerment Framework for Developing Mobile-based Applications: Empowering Sri Lankan farmers in their Livelihood Activities

By

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Dedication

With heartfelt gratitude, I dedicate this thesis to my loving parents.

To my mother (1932-2014) who was a pillar of strength since I was small,

who showed me the true meaning of resilience.

I will always remember your strong determination and selflessness.

To my father; who have shown me the simplicity of life and the power of patience.

I know that both of you are very proud of me.

Acknowledgements

While my name will appear alone on the front cover of this thesis, I am by no means its sole contributor. Rather, there are many of dedicated and inspiring individuals behind this piece of work who I would like to acknowledge and thank here.

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In this journey, I was blessed to be part of an international collaborative research group. It provided me with a rich experience of working with many talented individuals. I would like to thank Prof Gihan Wickramanayake and Dr Jeevani Gonethillaka from the University of Colombo, Sri Lanka for the tremendous support I received to organise many field trials and related activities. It was a valuable experience to work with Prof Genovetta Tortora, Prof Giuliana Vitiello and Dr Pasquale Di Giovanni from the University of Salerno, Italy. Working with other two PhD students (Sri Lanka) in this project; Lasanthi De Silva from University of Colombo and Anusha Walisadeera from the Ruhuna University, made this journey less lonely. Silently, you both made me work harder and catch-up with you, making me feel that I too was a full-time PhD student. Therefore, achieving our shared goal together has been one of the best moments in my life.

I also like to thank Australian Catholic University and Macquarie University for providing me support and facilities needed to do my research, and my colleagues for their wonderful support and encouragement.

I owe my deepest gratitude and special thanks to my friend and colleague; Dr. David Lindley. David has always been a great supporter in my journey. He has been there when I needed to let out many of my frustrations and when I couldn't write a single word on some days. He didn't let me dwell on it, rather acknowledged it as normal and gently guided me to have a better frame of mind. He also took upon the mammoth task of proof reading my thesis. Your maddening attention to details has made my thesis a much better one.

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Abstract

This thesis presents an empowerment framework, the aim of which is to underpin development of mobile-based applications that empower users in their livelihood activities. The work was carried out as part of an international collaborative project to develop a Mobile Based Information System (MBIS) for farmers in Sri Lanka. The project explored ways to overcome agriculture over-production problems. Due to lack of access to real-time, complete and relevant information, farmers often make poor decisions in their livelihood activities. Farmers only come to know, or realise, there is an oversupply when they bring their harvest to the market, and the oversupply reduces market price for the harvest, disadvantaging the farmers. Neither the farmers nor government agencies can make the necessary adjustments for lack of timely information regarding what farmers plan to cultivate, or have cultivated.

A mobile-based solution was used to solve this problem due to the high mobile penetration and affordable internet connections in Sri Lanka. Many mobile-based applications have been developed for agriculture domain. Undoubtedly, these solutions have enabled improved efficiency, competitiveness, productivity and income in many sectors of the economy, including agriculture. However, these applications only support part of the farming cycle and none of the projects explicitly address empowerment or how to motivate the targeted users to utilise the technology to its full potential.

The research aimed to address this gap by developing an empowerment framework that can be used to develop mobile-based artefacts. A Design Science Research methodology was selected to develop the empowerment framework because it is well suited for designing innovative artefacts. Two field trials were carried out in 2012 and 2013 to understand the goals of the farmers, obstacles they face in the agriculture environment, how they make decisions and what technology they use. From these insights and the knowledge gained through learning empowerment and related theory, an empowerment framework was developed.

The empowerment framework was used to develop an empowerment model with empowerment-oriented processes in the MBIS. These processes are embedded with choices and different types of customised knowledge to support meaningful and informed

decision making. This was followed by designing mobile interfaces for easy navigation through the application.

To evaluate the effectiveness of the empowerment framework on which the MBIS was developed, two further field trials were carried out to capture *before* and *after* data. In March 2015, at the beginning of a farming cycle, the MBIS was deployed and the farmers were provided with smart mobile phones to access the MBIS during their farming session. At the end of the farming season in September 2015, farmers met the researchers again. A questionnaire that was designed to measure the empowerment outcomes was used to gather data at the beginning and the end of the farming cycle. This data was analysed to determine the impact of the MBIS on empowerment outcomes of the farmers during the farming cycle.

The data was analysed to determine the impact of the MBIS on the empowerment outcomes, such as self-efficacy, sense of control and motivation, of farmers. The analyses revealed a statistically significant positive change of empowerment levels for most farmers. The average increase of the empowerment levels for the group because of using the MBIS were; *25% in self-efficacy, 11% in sense of control and 6% in motivation*. The results also showed some significant correlations between empowerment outcomes of farmers. This supports the established theory on the relationships of the empowerment outcomes. The usage of the MBIS was further analysed by using the logs of various activities farmers carried out on the application. These showed that there was a significant correlation between how farmers used the application and behaviour which is dependent on motivation, self-belief and ability. These results validated the correctness of the empowerment framework.

The impact and generalizability of the framework and artefact is evident. The MBIS has been adopted by the Sri Lankan Government and gained the attention of the Indian Government. Others are employing the framework in new agricultural contexts such as dairy production and in the health domain to empower diabetic patients. It is hoped and anticipated that the empowerment framework used for designing the MBIS in this thesis will improve the livelihood and daily life of many not only in developing countries and beyond.

Publications

Results of the research leading to this PhD thesis have been published in various international and national conferences and book chapters. The multi-authored publications were a result of achieving several milestones and discovering new knowledge of the overall collaborative project. The contribution that Ms Ginige made in the multi-authored publications is described below.

1. Ginige, A., Walisadeera, A. I., Ginige, T., Silva, L. D., Giovanni, P. D., Mathai, M., Goonetillake, J., Wikramanayake, G., Vitiello, G., Sebillo, M., Tortora, G., Richards, D., and Jain, R. (2016, October). *Digital Knowledge Ecosystem for Achieving Sustainable Agriculture Production: A Case Study from Sri Lanka*. Paper presented at the 3rd IEEE International Conference on Data Science and Advanced Analytics, Montreal, Canada.

   This publication discusses how an enhanced information flow model of context specific, dynamic situational information in agriculture domain, an agricultural ontological database and empowerment-oriented farming processes can be used to create a digital knowledge eco-system to achieve sustainable agriculture production. The contribution of Ms Ginige was the section that describes how farmers were empowered and the overall discussion. Contribution = 30%.

2. Silva, L. D., Ginige, T., Giovanni, P. D., Mathai, M., Goonetillake, J., Wikramanayake, G., Sebillo, M., Vitiello, G., Tortora, G., Tucci, M., and Ginige, A. (2016). Interplay of Requirements Engineering and Human Computer Interaction Approaches in the Evolution of a Mobile Agriculture Information System. In A. Ebert, S.R. Humayoun, N. Seyff, A. Perini and S.D.J. Perini (Eds.), *Usability and Accessibility Focused Requirements Engineering: Bridging the Gap between Requirements Engineering and Human-Computer Interaction* (pp. 135-159). Germany: Springer International Publishing.

This publication discusses how different theories and methods both from Requirements Engineering (RE) and Human Computer Interaction (HCI) were combined on a need basis to successfully gather the requirements when developing the Mobile-based Information System. When the process was retraced, there was a definitive systematic pattern as to how RE and HCI can be used to develop similar mobile artefacts. The discovery of this pattern enabled to generalise the process of developing mobile-based applications to empower users in their livelihood activities. Ms Ginige wrote 30% of the paper, especially relating to HCI aspects.

3. Ginige, T and Richards, D. (2015, August). *Measuring Empowerment to evaluate the impact of a Mobile Based Information System for Sri Lankan farmers*. Paper presented at the 21st Americas Conference on Information Systems, Puerto Rico.
4. Silva, L. D., Goonetillake, J., Wikramanayake, G., Ginige, A., Ginige, T., Giovanni, P. D., Walisadeera, A. I., Mathai, M., Vitiello, G., Sebillo, M., and Tortora, G. (2014, August). *Design Science Research Based Blended Approach for Usability Driven Requirements Gathering and Application Development*. Paper presented at the 2nd International Workshop on Usability and Accessibility focused Requirements Engineering, Karlskrona, Sweden.

   This publication discusses the challenges of extracting user requirements in designing innovative ICT based solutions for emerging vague or wicked problems. To address this challenge, several techniques in Software Engineering (SE) and Human Computer Interaction (HCI) within a Design Science Research (DSR) framework were blended. These techniques were traditional surveys and interviews, causal analysis, scenario creation and transformation, use of paper-based and functional prototypes for communicating with users and capturing their feedback, user centered design, and incremental development. This approach enabled to better capture requirements based on usability aspects and design a successful solution. The contribution of Ms Ginige was to describe the survey results. Contribution = 10%.

5. Ginige, T., Richards, D., and Hitchens, M. (2014, December). *Cultivation Planning Application to enhance Decision Making among Sri Lankan Farmers*. Paper presented at the Pacific Rim Knowledge Acquisition Workshop, Gold Coast, Australia.
6. Ginige, A., De Silva, LNC., Ginige, T., Giovanni, P.D., Walisadeera, A.I., Mathai, M., Goonetillake, J., Wikramanayake, G., Vitiello, G., Sebillo, M., Tortora, G., Richards, D., and Jain, R. (2014, September). *Towards an Agriculture Knowledge Ecosystem: A*

Social Life Network for Farmers in Sri Lanka. Paper presented at the 9th Conference of the Asian Federation for Information Technology in Agriculture, Perth, Australia.

> This publication proposes a conceptual architecture for an Agriculture knowledge eco-system as a result of series of iterative relevance and design cycles based on Design Science Research methodology. The proposed architecture has four layers: information aggregation/disaggregation layer, information flow and storage layer, user empowerment process layer, and user experience layer. This architecture can enhance the flow of information in the agriculture domain by aggregating or disaggregating information produced by some stakeholders to be consumed by others. The various modules in the application will make use of all these layers, creating a matrix structure. This architecture provides a good basis to manage the complex applications. The contribution of Ms Ginige was to explain empowerment process layer and prepare the overall architecture diagrams. Contribution = 30%.

7. Ginige, T and Richards, D. (2013, December). *Development of mobile-based empowerment processes for Sri Lankan framers.* Presented at the 24th Australasian Conference on Information Systems, Melbourne, Australia.
8. Giovanni, P. D., Romano, M., Sebillo, M., Tortora, G., G., Vitiello., De Silva, L., Goonethillake, J., Wickramanayake, G., Ginige, T., and Ginige, A. (2012, June). *User Centered Scenario Based Approach for Developing Mobile Interfaces for Social Life Networks*. Paper presented at the 34th International Conference on Software Engineering Zurich, Switzerland.

   > There are many research challenges that need to be resolved when developing mobile-based information systems. One major research challenge is to develop a suitable user interface for mobile devices. When developing these interfaces in addition to the required functionality, there are many other factors that needs to be taken into consideration: level of literacy of the users, familiarity in using the device, users' cultural background, language beliefs and the sophistication and functionality of the mobile device user can afford. This paper reports the investigation into developing a suitable user interface for a Social Life Network application for the farmers in Sri Lanka. The contribution of Ms Ginige was writing the scenarios. Contribution =10%.

9. Ginige, T and Richards, D. (2012, December). *A Model for Enhancing Empowerment in Farmers using Mobile Based Information System*. Paper presented at the 23rd Australasian Conference on Information Systems (ACIS 2012), Geelong, Australia.

10. Ginige, A., Ginige, T., and Richards, D. (2012, June). *Architecture for Social Life Network to Empower People at the Middle of the Pyramid*. Paper presented at the 4th International United Information Systems Conference, Yalta, Ukraine.

    This publication presents a possible design of an architecture for a mobile based information system to empower people in the middle of the pyramid (MOP). MOP has half of the world's population connected to the Internet via a mobile phone. They need applications to enhance their livelihood activities. These applications need to provide information on rapidly changing dynamic situations such as fluctuations in market prices, prevailing supply and demand situation for their produce as well as more stable information such as information on seeds, pests, weather patterns, soil types etc. This architecture is designed to provide dynamic information by aggregating micro-blogs, status updates and data from sensors. It also has connections to established data sources and websites to provide more stable information and tools for empowerment. The contribution of Ms Ginige was to design the initial architecture of the application based on empowerment processes. Contribution = 40%.

11. Giovanni, P. D., Romano, M., Sebillo, M., Tortora,J., Vitiello, G., De Silva, L., Goonethilaka, J., Wikramanayake, G., Ginige, T., and Ginige, A. (2012, September). *Building Social Life Networks through Mobile Interfaces: A Case Study of Sri Lankan Farmers*. Presented at the 9th Conference of the Italian Chapter of AIS, Rome, Italy.

    The development of mobile applications is paramount to support users living in developing countries to improve their lives. One of the major research challenges is to develop a user interface suitable for such users. This paper discusses the design process applied to develop a mobile application for the farmers living in Sri Lanka. The application prototype was developed and evaluated against usability requirements. The contribution of Ms Ginige was to provide an input to design the initial user interfaces. Contribution = 10%.

12. Ginige, T. and Ginige, A. (2011, December). *Towards Next Generation Mobile Applications for MOPS: Investigating emerging patterns to derive future requirements*. Presented at the 12th International Conference on Advances in ICT for Emerging Regions, Colombo, Sri Lanka.

Statement of Candidate

I certify that the work in this thesis titled "An Empowerment Framework for Developing Mobile-based Applications: Empowering Farmers in their Livelihood Activities" has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree to any other university or institution other than Macquarie University.

The thesis is an original piece of research and it has been written by me.

Any help and assistance that I have received in my research work and the preparation of the thesis itself have been appropriately acknowledged.

All the information sources and literature used are properly stated in the thesis.

This research was conducted with the approval of the Macquarie University Human Ethic Committee. Reference number: 5201200767 (Appendix G).

Tamara Ginige

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1 Introduction

Over the last three decades, the advances in Information and Communication Technologies (ICT) have dramatically changed many aspects of our lives. As members of the networked society, we constantly interact with ICT with regards to various aspects of private and business lives. This was enhanced by two way interaction and user participation provided by the current Web 2.0 applications. (Cormode and Krishnamurthy 2008). The same users who consumed information also became the information producers which can be seen as an empowerment of previously passive information consumers. Toffler has called these users *prosumers*; who are both producers and consumers (Toffler and Toffler 1990). Current Web 2.0 applications empower users as it is a venue for personal expression, sharing, communicating and collaborating with others. These web based utilities and the tools that focus on social, collaborative, user-driven content and applications facilitate a more socially connected Web. The users in this connected Web are the creators of user-generated content in a virtual community (Paily 2013).

These new technology developments have opened many new possibilities. However, not everyone in our global community has equal access to these technologies or the possibilities they could afford. Much of the information technology developed is designed for the Western world and for individuals, groups and organisations that typically have access already. In addition, they enjoy certain levels of empowerment including knowledge, choices, decision-making, computer literacy that enable them to utilise technology.

This research was inspired to solve an over production agriculture problem in Sri Lanka that sometimes led to farmers committing suicide (Senaratne 2005). Studies in India, Sri

Lanka, USA, Canada, England and Australia have identified farming as one of the most dangerous industries associated with a high suicide rate than in general population (Behere and Bhise 2009). A recent report from the World Health Organization ranks Sri Lanka as the 4th most suicide prone country in the world (Amaranath 2012; Telegraph 2014; WHO 2016). In Sri Lanka, the trends of suicide and self-harm have followed the use and availability of pesticides. Farmers are often exposed to a high rate of stress. Physical stressors and hazards of the farm environment are compounded by regulatory framework and economic dynamics of managing farm business. These operate in the context of declining trends of trade for agricultural produce, volatile commodity markets, limited availability of off-farm employment, growing cost of machinery and production and loss of farm or livelihood due to crop failures. (Ramesh and Madhavi 2009).

Most farmers in Sri Lanka depend on their self-knowledge, friends, family or a village middle-person for advice and information that may not be accurate, up-to-date or complete (Lokanathan and Kapugama 2012). Sometimes, unknowingly, most of the farmers in one area grow the same crop, that results an oversupply market with low selling price. Often farmers borrow money from the money lenders with very high interest rates and sell their harvest to them to settle the loans. This limits the opportunity of farmers getting a better price for their harvest, leaving farmers with very little money at the end of their farming seasons.

Research had shown a relationship between monetary and family problems with suicide (Melberg 2003). Further, there is no customary or mandatory retirement age for farmers all over the world and many tend to work beyond the customary retirement age, placing the younger generation in a dependant relationship with their parents for much longer than is typical (Behere and Bhise 2009). This can lead to tension between the two

generations on the farm. The situation described above leaves farmers feeling powerless, trapped, helpless, desperate, and they do not see their livelihood is improving.

The main aim of this thesis was to *develop and validate an empowerment framework for developing mobile-based applications to empower users* who are in desperate situations as described above, to take actions to change and improve their lives. In this study, we draw on the psychology literature and the related literature on empowerment studies to provide a theoretical basis for understanding of empowerment and investigate how those who are not empowered can improve their livelihood through technology.

1.1 What is empowerment?

Empowerment is a concept that is studied extensively across many areas such as psychology, community development, education, social studies, and organisations among others (Perkins and Zimmerman 1995; Rapport 1987; Zimmerman 1988; Zimmerman 2000). Within each perspective, empowerment is central to the work of improving human lives. It encompasses a sense of personal control, which has been linked clearly to greater health and well-being (Chandola et al. 2004; Griffin et al. 2002; Sue 1978). Empowerment has different meanings in different sociocultural and political contexts, typically involving the use of terms such as self-efficacy, control, self-power, self-reliance, independence, making one's own decisions, and being free to define it (Narayan 2002). The two definitions of empowerment that have inspired significant research are the "ability to get what one wants, and the ability to influence others to feel, act, and/or behave in ways that further one's own interests" (Dodd and Gutierrez 1990, p. 64) and "the capacity to exert control and influence over decisions that affects one's life space for one's own benefit" (Zimmerman 2000).

The empowerment process is driven by a set of meaningful goals a person might pursue. Understanding the nature of such goals and how they differ across people and contexts is

critical to facilitating the process of empowerment (Cattaneo and Chapman 2010). To achieve these goals, one must act. The action is driven by the meaningful goals, motivated by the personal value of those goals and beliefs about one's ability to reach those goals, informed by relevant knowledge, and carried out using relevant skills (Freire 2000).

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. Therefore, an evaluation of outcomes is important to provide necessary feedback for the continued evolvement of empowerment processes. Empowerment is country, population, domain, context and level specific hence empowerment processes and outcome vary significantly across these dimensions (Alsop and Heinsohn 2005; Zimmerman 2000). Therefore measuring empowerment is a complex process and a single framework or standard cannot fully capture its meaning for all people in all contexts (Bandura 1994; Zimmerman 1995). Despite the great interest in studying the influence of empowerment across many areas, the development of technology-focussed frameworks to evaluate and monitor empowerment systematically is still at its very early stage.

Many researchers have described empowerment as an iterative process of gaining power with interactions at all levels (Masterson and Owen 2006; Speer and Hughey 1995; Wallis et al. 2008). This iterative process involves true reflection which leads to action (Freire 2000). In his qualitative study of emerging citizen leaders in grassroots organizations, (Kieffer 1984) has concluded that the longer participants extend their involvement, the more they understand, motivated, proactive, develop their skills and more likely to continue.

There is a growing consensus that the concept of empowerment is multilevel and can be analysed at multiple levels such as individual, organisational and community (Perkins and Zimmerman 1995). These interactions at different levels have profound consequences of how people view themselves. Though analysis can be done at different levels, individual, organisational and community empowerment are mutually inter-dependent and are both a cause and a consequence of each other (Zimmerman 2000). Similarly, empowering processes at one level of analysis contribute to empowerment outcomes at other levels of analysis. Therefore, empowered individuals are the main basis for developing empowered communities and organisations.

1.2 Features of current mobile-based solutions in agriculture domain

To reap the full benefits from the mobile revolution in the developing countries, there should be affordable mobile devices with easy access to mobile internet infrastructure and mobile applications that help users in their livelihood activities. Agriculture is one of the major economic sectors of many developing countries: Sri Lanka 33% (Agriculture 2015), India 25% (HindustanTimes 2015), Africa 65% (Africa 2013).

The current rapid growth in the mobile communications, in particular development of high speed mobile broadband networks and greater affordability of devices and adoption of smart phones, have made it feasible to develop mobile-based solutions in many areas in the developing world, including Agriculture. There have been many successful projects to enhance some sections of the supply chain of farming and bring many economic and social benefits.

For example, there are some mobile-based extension and knowledge systems in India; *Avaaj Otalo* is a service for farmers to access relevant and timely agricultural information over the phone (Patel et al. 2010), *eSagu* is an agro-advisory solution to improve productivity (B. V. Ratnam et al. 2006) and *mKrish* is an agro- advisory service to address

the issues of farmers (Pande A. K. et al.). Market information systems in developing countries are targeted especially at providing market information (Kopicki and Miller 2008; Kuek et al. 2011; Magesa et al. 2014; Parikh et al. 2014). In these projects, farmers and sellers are connected by providing commodity prices and market information using SMS or the Web.

In Kenya, KACE, DrumNet (originally a project of PRIDE AFRICA) and CGIAR mobile applications provide market information to farmers and create links between farmers and markets (CGIAR 2014; DrumNet 2005; KACE 2015). ESOKO and mFarms mobile applications in Ghana provide crop production and market information to the farmers (eSoko 2015; mfarms 2013). RATIN is another mobile application that provides real time, relevant and accurate market information in five Eastern African countries including Kenya, Uganda, Tanzania, Burundi and Rwanda (RATIN 2015). INFOTRADE Mobile is a project that was developed in Uganda and provides up-to-date agricultural prices for queries from farmers (INFOTRADE 2008). The Grameen foundation in Kenya has been developing a mobile application to help smallholder maize farmers properly store and manage crops, link to a financial institution to receive financial help against the value of their stored crop and connect with markets for final sale. (Grameen 2002).

1.3 Gaps in current mobile-based solutions in Agriculture domain

The mobile-based solutions identified in section 1.2 are designed for farmers to receive information in a passive mode. In addition, the projects like above focus on one or two stages of a full farming life cycle. For example, many projects aim to provide market and selling prices. This information is most valuable at the end of a farming cycle. However, in a full farming cycle, there can be as many as six stages that have different information needs and activities. (De Silva and Ratnadiwakara 2010). Therefore, to achieve a good

profit at the end of a farming cycle, it is important to make informed decisions from the beginning of a crop cycle and at each stage.

Further, none of these mobile-based solutions developed for farmers in developing countries, explicitly address empowerment or motivate targeted users to utilize the technology to its full potential. These applications were not developed based on empowerment related concepts such as self-efficacy or sense of control or motivation.

1.4 Aim of the Thesis

To respond to the gaps identified above, lack of empowerment in current mobile-based solutions for agriculture and support for informed decision making for full farming cycle, in this research, designing of a mobile-based solution based on an empowerment framework which empower users in their livelihood activities was investigated. The rapid growth of smart phones and mobile infrastructure, user empowerment features in Web 2.0, and the importance of providing relevant and different types of information for the full farming cycle, were considered to address the gaps in current mobile solutions.

Thus, the aim of this research was to - *Develop and validate an empowerment framework for developing mobile-based applications to empower users in their livelihood activities*.

To achieve this aim, a review of available literature was conducted which is reported in chapter 2, the gaps in current mobile-based solutions for agriculture in relation to the above aim were identified and 3 research questions were formulated. These research questions are presented in Chapter 3.1.

This study is part of a broader study conducted on the agriculture over-production problem in Sri Lanka. In this thesis, the words “I” and “we” will be used to distinguish the individual contribution of *this thesis* and overall contributions of the collaborative project respectively.

1.5 Broader Context

In August 2011, an international collaborative research team with members from Sri Lanka, Australia, Italy and 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. To address these issues, five higher degree students (4 PhDs and 1 Master) from Sri Lanka, Australia and Italy investigated different aspects of the research problem.

a) Agriculture Information Eco System (PhD in Sri Lanka):

   In daily activities, stakeholders in any domain generate valuable information. In order to achieve its full potential, this information should reach right people at the right time in a useful format to make informed decisions. One of the issues in the agriculture domain in Sri Lanka was the inefficient and almost non-existent information flow model among the stakeholders. In most cases, the information flow was open and did not involve all the stake holders. For example, farmers did not know what others were growing and as a result there was either too much or too little supply of the crops in the market. This information in aggregated form was not received by fertiliser or pesticide suppliers and sometimes it led to a scarcity of these items in the market. This became a significant factor in a case of disease or pests as there were not enough in the market to control the situation immediately. Further, current information models did not recognise which information or its form was required by a stakeholder (see Appendix F).

   To address these issues, agriculture information eco system was developed. First the current information flow model was improved by identifying all the stake holders involved in the agriculture domain. Then using aggregation and disaggregation techniques, the information needed by stakeholders, were mapped

to information generated by others to encourage information sharing and reap the benefits of using current and relevant information in decision making.

b) User Centered Agriculture Ontology (PhD degree in Sri Lanka):

Farmers in Sri Lanka have been affected by not being able to get vital information required to support their domain related activities in a timely manner. Some of the required information can be found in government websites, agriculture department leaflets, newspapers, etc. Most of the required information was unstructured, incomplete, in varied formats, and difficult to access. Therefore, finding the right information in a suitable format and in a timely manner was a challenge. To address this challenge, a user-centred, agricultural knowledge repository was built. The online knowledge-base with a SPARQL endpoint was created to share and reuse the domain knowledge that can be queried based on user context. A semi-automatic, end-to-end ontology management system was developed to manage the developed ontology as well as the knowledge-base. It provides facilities to reuse, share, modify, extend, and prune ontology components as required (see Appendix F).

c) Empowerment framework for a Mobile-Based Information System to empower users in their livelihood activities (PhD degree in Australia. ***This Thesis***)

As discussed in (a) and (b) above, one of the farmers' major issues was not having access to real-time, complete, accurate information with which to make informed decisions in their livelihood activities. In developing countries, information and communication technology (ICT) solutions have been used to improve access to the necessary information. These solutions have enabled efficiency improvements, competitiveness, productivity and income in many areas, including agriculture. While these have brought many benefits in their own context, none explicitly addressed empowerment or how to motivate the targeted users to utilise the

technology to its full potential. Access to information itself is not enough. Technology should be used to design processes to identify the needs of the users in the environment in which the users operate and empower them to use these processes to achieve their goals. Currently there are not many mobile applications that have been developed to address the local needs of farmers.

In this research, a detailed analysis was carried out to find out how farmers work in their environment, the obstacles and opportunities they have, their goals, their current farming processes, how they make decisions, what knowledge they need to make informed decisions and their technology usage. Then a detailed study of empowerment was undertaken to understand the various components of psychological empowerment, key drivers and influences of empowerment and their relationships to each other. This knowledge was then used to design an empowerment framework that has elements such as an empowerment model empowerment oriented farming processes with choices, and different types of relevant, up-to-date and customised knowledge. The Mobile-based Information System (MBIS) was implemented based on this framework. To evaluate the MBIS as an empowerment tool, farmers' level of empowerment before and after use of the MBIS was measured.

d) Context-based content aggregation for Social Life Networks (Master degree in Australia)

One of the main requirements of the overall project was to provide relevant information to users to support them achieving their goals. This research focussed on identifying factors specific to the farming domain and providing information in a relevant context for the farmer. For this purpose, a farmer-context model was developed.

The attribute values of the context model were obtained by capturing the current situation associated with the user. The situation of the user has temporal, spatial and profile attributes which are captured and updated at run time from the sensory device of the mobile phone. Using basic timestamp information obtained from the mobile device not only the date and time of the query but also the corresponding growing season names were derived to be used for querying the ontological knowledgebase. Using a Geographical Information System (GIS) location information captured as Geo-coordinates from the mobile device is mapped to both corresponding administrative district for identify related physical resources and markets and agro-ecological zone for obtaining related climatic, elevation and soil conditions. The profile attributes were captured at the time a user register to access the system and can be updated manually by user at any time. When user request for some information the related contextual information derived above is added to the query to obtain a personalised response.

e) Enhancing Ubiquitos Computing Environments through composition of heterogeneous services (PhD degree in Italy)

In recent years substantial advancements in information and communication technologies have enabled the development of original software solutions to problems faced by people in their daily activities. Among technical advancements that have fostered the development of such innovative applications was the gradual transition from stand-alone and centralized architectures to the distributed ones and the explosive growth of mobile communication. The profitable combination of these advancements has led to a rise of Mobile Information Systems. However, developing these systems is challenging and several aspects should be considered during the design and development of both

the front and back ends of the proposed solution. One of the aspects that was investigated in this project was the elicitation of requirements and the design of usable mobile user interfaces. Usability requirements play a key role in the success of the work carried out in (a), (b), (c) and (d). In this research, a methodology was developed to support the design of mobile solutions with special attention to design of user interfaces to minimise loss of information when information flowing from system to user and back.

1.6 Dissertation Outline

In this section, the outline of this thesis is described.

Chapter 2: Background and Related Literature. This chapter presents the previous work related to this research. It mainly encompasses the technology development in the world and the empowerment. In the technology development in the world, we present the mobile penetration in the world and the developing countries, features of the current mobile solutions in the farming domain and the gaps, and the nature of the current problem farmers face in Sri Lanka. Under empowerment, the theory and concepts related to empowerment and current applications to support the empowerment will be presented.

Chapter 3: Research Methodology. This chapter presents three research questions that were investigated to achieve the main aim as stated in section 1.4 and the Design Science Research (DSR) as the chosen research methodology to address these questions.

Chapter 4: Towards an empowerment framework. This chapter addresses the first research question: *How can farmers be empowered in their livelihood activities*? It involves understanding the goals, opportunities and obstacles farmers have, defining a working definition in the context of Sri Lankan farmers, developing an initial conceptual empowerment model, investigating how technology can be used to empower farmers, and

how farmers make decisions. The work carried out in this chapter report the journey and the findings that eventually helped to implement the empowerment framework.

Chapter 5: Empowerment Framework and Design of Mobile Based Information System (MBIS). This chapter presents how we addressed the second research question*: How to design a suitable MBIS (artifact) to empower farmers?* This chapter presents the elements of the empowerment framework. Then it presents the detailed designs of Mobile-based Information System that was developed based on the empowerment framework.

Chapter 6: Evaluation of Empowerment Framework. This chapter presents the third research question: *How to evaluate the effectiveness of the empowerment framework?* It presents the instruments that were implemented to measure empowerment outcomes, how the artefact was deployed with the farmers in Sri Lanka, how the data was collected before and after the deployment of MBIS, how data was analysed to measure the impact of MBIS on the empowerment outcome and the results.

Chapter 7: Discussion and Conclusion. In this final chapter, a summary of how this research project fulfilled the aim and major outcomes achieved will be provided. It also presents the contribution made to the research community, the progress of the overall project and the impact it had made in Sri Lanka. It is followed by an overall reflection, suggestions for future research, and finishes with a brief discussion of opportunities and limitations of the research project.

2 Background and Related Literature

This chapter presents the previous work related to this research. It mainly encompasses the technology development in the world, agriculture in Sri Lanka, the empowerment and the applications to support empowerment. In the *technology development in the world* section, it discusses the Web 2.0 applications, and mobile penetration in the world and the developing countries. In the next section, it discusses the *Agriculture in Sri Lanka*, the main domain this research focusses on, related organizational systems and the nature of the current problems in the agriculture domain. Under *empowerment*, it presents the theory and concepts related to empowerment. The final section of this chapter discusses the current mobile-based agriculture solutions in developing countries. Finally, because of the research investigation, it describes the research gaps in these solutions and the importance of addressing them.

2.1 Technology Development in the world

This section explores enabling technology related factors that makes it now possible to develop new applications.

2.1.1 Web 2.0 Applications

Because of Web 2.0, a range of new applications such as blogs and wikis, and websites such as Facebook, Wikipedia, and YouTube have emerged. Founded in 2004, Facebook has become one of the most popular social networking websites with 1.71 billion monthly active users (Facebook 2015; Statista 2016). Social interaction is the dominant feature of Facebook with a billion people interconnected share contents in several mediums and use *review* function in the application to collect large amounts of reviews to support knowledge aggregation. This dominant social interaction has enabled users to create different networks amongst likeminded who organise online events for action taking (Ginige and Fernando 2015). Two examples of the role of social media in collective

actions are the ESDA Revolution in the Philippines (Liu and Gastardo-Conaco 2011) and the protest in twenty one Arab countries and the Palestine Authority: Arab Spring (Wolfsfeld et al. 2013). In 2001 in the Philippines, a massive protest was organised against then corrupt president predominantly using nearly seven million text messages. Three days after the protest had started; the fate of the leader was sealed, marking the occasion as the first event that social media helped to force out a national leader from that role. In 2011, protest demonstrations were held to end corrupt government throughout the Arab world, beginning in Tunisia and quickly spreading to other countries. Though there were many harsh media censorships of many of the countries, the social media enabled the creation of social and emotional connections across boundaries. It played a major role to create a cohesive, single, mass uprising by linking all the simultaneous events which is now referred to as the Arab Spring (Eltantawy and Wiest 2011; Wolfsfeld et al. 2013). Despite the type of the end outcome, in the recent years, there have been similar collective actions supported by the social media: quick ouster of Spanish Prime Minister of Spain in 2004 as a result of demonstrations organised by text messaging (Avendaño and Montserrat 2010), London Riots (Tonkin et al. 2012), Student and Environmental Protests in Chilli (Scherman et al. 2015),

Google-owned online video-sharing service, YouTube is one of the other most popular websites worldwide that has created an active online community. You Tube was founded by three former PayPal employees in 2005 to display user-generated and corporate media videos (Graham 2005). You Tube has more than 1 billion unique users visiting the site per month. The video network enables users to upload, view and share videos and also allows registered users to comment upon videos and to compile playlists (Statista 2015). The growth in watch time on YouTube has accelerated and is up at least 50% year over year for three straight years. YouTube is localized in 88 countries and can be accessed in 76 different languages, which covers 95% of the world's internet population (Statista 2015).

Another trend that has emerged is where people collaborate to generate new knowledge and share that knowledge. Hardcopies of encyclopaedia have disappeared and been replaced by online encyclopaedias, termed as wikis. There are many wikis such as online Encyclopaedia, Wikibooks, Wiktionary, WikiHow, and Ekopedia to name a few. Wikipedia, is the most popular wiki and has more than 37 million different pages, all created by users (Wikipedia 2015). Wikipedia is ranked amongst the ten most popular websites and constitutes the Internet's largest and most popular general reference work. As of February 2014, it had 18 billion page views and nearly 500 million unique visitors each month (Wikipedia 2015). Another development was the emergence of educational applications to share knowledge. Started in 2012, Coursera is one such educational application that offers massive open online courses (MOOCs) and today it has more than 15.2 million learners, 1340 courses and 127 partners (Coursera 2015).

With the development of new applications, new business models too have emerged. Some initial social connection networks have now evolved into many professional and marketing networks resulting new business models such as LinkedIn. Several other business oriented applications with new business models have emerged and become very popular in a short period of time. To name a few, *Airbnb* - an accommodation sharing application founded in 2008 with millions of guests across 34,000 countries (Airbnb 2015), *Uber* - a ride sharing application with more than 8 million users (Uber 2015), *TaskRabbit* – a mobile marketplace for people to hire people to do jobs and tasks, from delivery to handyman to office help (TaskRabbit 2015), *DogVacay* – hosting service where dog owners can leave their dog with a host who will take care of the dog when the owners are out of town (DogVacay 2015), *GetAround* – a peer-to-peer car sharing company lets people borrow cars from others (Getaround 2015) and *Fon* - a Wi-Fi network that enables people to share some of their home Wi-Fi network in exchange of getting free Wi-Fi from anyone of the 7 million people in Fon's network (Fon 2015).

Growth of such applications has formed the basis for emerging concepts such as *Collaborative Consumption* (Belk 2014*)* and *Sharing Economy* (Hamari et al. 2015) which have disrupt the established business models.

2.1.2 Connectivity - Mobile Penetration in the world

Mobile is the recent technology that has had a profound impact on national economies worldwide, particularly in the areas of job creation and economic growth. Increasingly ubiquitous and higher speed mobile networks contribute to many aspects of economic, political and social life in both developed and developing regions. At the end of 2015, there were a total of 3.6 billion unique mobile subscribers (51% of the global population) and 7.1 billion global SIM connections (GSMA 2015). The world is seeing a rapid technology migration to both higher speed mobile broadband networks and an increased adoption of smartphones and other connected devices. Mobile broadband connections will account for almost 70% of the global base by 2020, up from just fewer than 40% at the end of 2014. Smartphone adoption is already reaching critical mass in developed markets, with the devices now accounting for 60% of connections. It is the developing world driven by the increased affordability of devices that will produce most of the future growth, adding a further 2.9 billion smartphone connections by 2020 (GSMA 2015).

2.1.3 Mobile and internet access in the developing countries

Despite the progress of mobile development, its full potential is yet to be realised. Populations need access both to mobile broadband networks, affordable devices and services. According to ITU, the global internet users grew from 1.6 billion in 2008 to 2.9 billion by the end of 2014, accounting for 40% of the global population (ITU 2015). This leaves 60% of the global population still unconnected. This has the potential to hinder opportunities for economic and social development in many developing countries. However, this current gap in internet access will largely be addressed by mobile

networks. Mobile cellular telephone subscription in the developed, developing and world by the end of 2015 was 120.6%, 91.8% and 96.8% respectively (ITU 2015), Figure 2-1). And that of Active mobile broadband subscription was 86.7%, 39.1% and 47.2% respectively (ITU 2015), Figure 2-2).

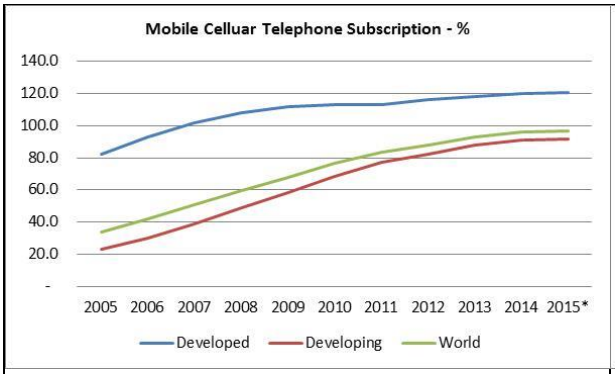

Figure 2-1: Mobile Cellular Telephone Subscription (source: ITU 2015)

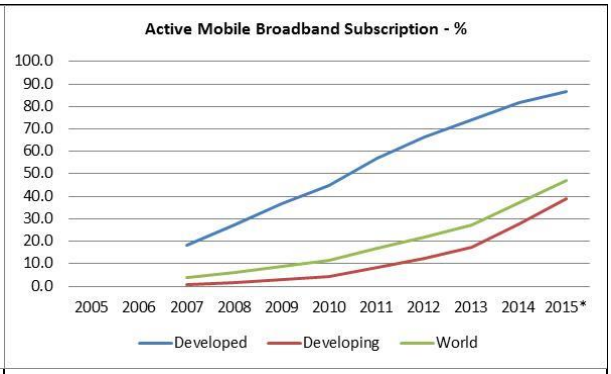

Figure 2-2: Active Mobile Broadband Subscription (source: ITU 2015)

The unconnected population mainly in the developing countries that live predominantly in rural areas with characteristics such as low incomes, high levels of illiteracy, poverty, rapid population growth, and in some areas, with the impact of political instability (Hellström 2010). However, the predominant mobile infrastructure in developing countries that is available to a larger proportion of the population than many other basic services, such as electricity, sanitation and financial, can make a profound impact. A simple feature mobile phone can provide communications and basic services to currently disadvantaged populations. Mobile can act as an enabler when other traditional delivery mechanisms fall short, and it is already being used to provide underserved populations with access to information and services (GSMA 2015). According to McKinsey, if internet access achieves an impact on the same scale as mobile telephony has in Africa, it could account for as much as 10% of total GDP by 2025. This would be equivalent to over US$300 billion, due to internet's transactional effects on sectors such as retail, agriculture and healthcare (McKinsey&Company 2015).

2.2 Agriculture in Sri Lanka

In the Sri Lankan economy, agriculture is one of the important sectors and approximately 33% of the total labour force is engaged in agriculture (Agriculture 2015). Since the beginning of 20th century, agriculture in Sri Lanka has been dominated by four crops; rice, tea, rubber and coconut. Most tea and rubber are exported, whereas almost all rice was for internal use. The coconut crop is sold on both domestic and international markets. Accelerated Mahaweli Program irrigation project opened a large amount of new land for paddy cultivation in the dry zone of the eastern part of the island. In contrast, the amount of land devoted to tea, coconut, and rubber remained stable in the forty years after independence in 1948. Land reforms implemented in the 1970s affected mainly these three crops. Little land was distributed to small farmers; instead it was assumed by various government agencies. As a result, most tea and a substantial proportion of rubber production was placed under direct state control (Ross and Savada 1988).

Farming rice, vegetables, fruits or other crops is the most important activity for most people living in rural areas of Sri Lanka. They grow these crops in their own farms or leased ones that may be of few hectares in size. Some paddy fields are surrounded by a belt of residential gardens which are smaller in size. They are permanently cultivated with fruit trees and vegetables. The gardens in turn are surrounded by forests, parts of which are temporarily cleared for slash-and- burn cultivation, known as *chena*. Various grains and vegetables were grown on *chena* lands (Ross and Savada 1988).

2.2.1 Agriculture domain and related organisational systems in Sri Lanka

Agriculture domain in any country is complex. During the last two decades, agriculture in Sri Lanka has suffered from declining production and productivity (Gunawardana and Somaratne 2000; NASTEC 2002). The effects of globalisation, inconsistent agricultural policies that do not support current environment, information gap in policy formulation,

lack of research and development in agriculture and the absence of holistic approach for the all stakeholders in the agriculture were identified as some of the reasons for the current situation in the agriculture sector in Sri Lanka (Abeygunawardane 2014). Climate and economics report, ADB (2014) predicts that six Asian countries including Sri Lanka will see an average economic loss of around 2% of their GDP by 2050 due to widespread degradation of coastal and agricultural resources (ADB 2014). Water management in farming is another major issue. An improved and effective water management system would give farmers more discretion over sustainable water use, promote diversification of crops and livestock, and increase farmers' incomes (IWMI 2010). Fertiliser subsidies represent a major component in agriculture policy in Sri Lanka (Abeygunawardane 2014). Over the years this has significantly contributed to increase paddy production. However there are issues over the effectiveness and sustainability of the program because of concerns around overuse of fertiliser for crops other than paddy, soil and water pollution, food safety and the burden on the national budget (Rodrigo 2015). When issues were found, subsidy policy has been reviewed and temporary solutions were adopted. Though there have been ample evidence to suggest that the long running subsidy schemes should end, it has continued due to the complex interplay of history, institutions, ideas, leadership, different actors and external influences (Abeygunawardane 2014).

2.2.2 Nature of current problems in the agriculture domain in Sri Lanka

The characteristics described in the Agriculture domain in Sri Lanka create a very complex environment where a change in one factor can lead to change another. For example, a change in the water policy may affect the type of crop to be grown as each crop needs a specific amount of water. This may be a new crop which is unfamiliar to a farmer therefore he/she may not be very familiar with the type of fertiliser to be used or different types of pest and diseases associated with that crop. In such situations where farmers do not have correct information, they spend money on items which are not suitable or

applicable. As a result, their expenses become higher. Further, if there is an unexpected weather situation such as a heavy rain or a drought, despite the type of the crop, it may further affect the harvest of that cultivation period (Verité-Research 2015). This ultimately affects the income generation of the farmer and welfare of the family.

There are six stages of a crop cycle: *deciding* stage where farmers decide what to grow, *seeding* stage where farmers either purchase or prepare seeds, *preparing and planting* stage, *growing* stage where farmers apply fertiliser, pesticides and water, *harvesting, packing and storing* stage and *selling* stage (De Silva and Ratnadiwakara 2010). Farmers often make wrong decisions due to the lack of access to current and relevant information. For example, during the deciding stage, farmers often choose to grow the same crop within a region, and this could cause a potential over supply of crops (Hettiarachchi 2011). Farmers only come to know, or realise, there is an oversupply when they bring their harvest to the market, and the oversupply reduces market price for the crop, disadvantaging the farmers. Neither the farmers nor government agencies can make the necessary adjustments for lack of timely information regarding what farmers plan to cultivate, or have cultivated. The yield could be affected by various other factors including availability of water, weather, and pests. There are similar issues at all the stages of the crop cycle (Lokanathan and Kapugama 2012). The result of such issues leaves farmers feeling powerless, helpless and desperate, and they do not see their livelihood is improving. In the past, some very unhappy farmers have attempted to commit suicide in desperation (Senaratne 2005). Some farmers have stopped farming and have started to look for other jobs.

2.3 Empowerment

In the recent years, the development of new mobile-based applications has been driven by to meet the needs of the broader society. These needs are a combination of human

feelings such as trust, belongingness, self-esteem, motivation and perception to carry out their daily activities (Ginige and Fernando 2015). The different technological features can also be used to develop applications to empower users. Empowerment is a powerful concept that is linked to power. It has been defined as the "ability to get what one wants, and the ability to influence others to feel, act, and/or behave in ways that further one's own interests" (Dodd and Gutierrez 1990, p. 64) and "the capacity to exert control and influence over decisions that affects one's life space for one's own benefit" (Zimmerman 2000). Many researchers have described empowerment as an iterative process of gaining such power (Masterson and Owen 2006; Speer and Hughey 1995; Wallis et al. 2008). Empowerment has different meanings in different sociocultural and political contexts, typically involving the use of terms such as self-efficacy, control, self-power, self-reliance, independence, making one's own decisions, and being free to define it (Narayan 2002). Empowerment is of intrinsic value and can be applied at the individual and collective levels. In its broadest sense, empowerment is the expansion of freedom of choice and action. It means increasing one's authority and control over the resources and decisions that affect one's life. As people exercise real choice, they gain increased control over their lives.

2.3.1 Empowerment and related concepts

This section discusses the concepts and theory of empowerment. This study was related to the sub cycle "*Rigor – Learning (1)*" of DSR (See section 3.9).

Empowerment at the individual level of analysis can be referred to as psychological empowerment (PE) (Zimmerman 1988; Zimmerman 1995). Zimmerman (1995) defines three qualities of psychological empowerment (PE). *Intrapersonal Component* of PE refers to how people think about themselves and includes domain specific perceived control and self-efficacy, motivation to control and perceived competence. *Interactional Component* of

PE refers to the understanding that people have about their community and related socio-political issues. *Behavioural component* of PE refers to actions taken to directly influence outcomes. These three components of PE merge to form a picture of a person who believes that he or she has the capability to influence a given context (*Intrapersonal Component),* understands how the system works in that context (*Interactional Component)* and engages in behaviours to exert control in the context (*Behavioural component).*

2.3.2 Enablers of Psychological Empowerment

There are several other concepts related to psychological empowerment such as motivation, autonomy, meaningful goals, choices and locus of control. There have been many studies done to examine the relationships among these concepts. In the study of human motivation, goals have been identified as the key contributing factor to the long-term levels of well-being (Alsop and Heinsohn 2005; Austin and Vancouver 1996; Karoly 1999). Psychological well-being has been defined as "the self-evaluated level of the person's competence and the self, weighted in terms of the person's hierarchy of goals" (Lawton 1996, p328). Goals are necessary for daily functioning but they can be trivial and shallow and may not have the capacity to contribute to the sense of meaning. But the goals that are meaningful lend order and structure to these lives (Emmons 2003). Self-determination theory (SDT) (Deci and Ryan 2000) is an empirically tested theory of human motivation that has been applied and tested in a variety of life domains such as work, education, parenting, relationships, health and well-being, sports and psychotherapy. It discusses the importance of motivation and personally meaningful goals at length. The theory has long recognised that the basic physiological needs of autonomy, competence and relatedness are necessary for optimal functioning and for the integration of social norms and values in all life contexts.

Sense of Control

Another important concept is the *sense of control* of a person. It is defined as the perceived degree of freedom or discretion in carrying out work activities (Hall 1986). The perception that one is an effective agent in one's own life on the one hand, as compared to the belief that one is powerless to control important life outcomes, is central to self-control (Gecas 1989). The concepts related to the sense of control include mastery (Pearlin et al. 1981), locus of control (Rotter 1966), self-efficacy (Bandura 1997), instrumentalism (Wheaton 1980) and personal autonomy (Seeman and Anderson 1983). The sense of personal control is important scientifically for many reasons. Most important, it reflects the real constraints and opportunities of one's ascribed and achieved statuses. Perceptions of control conform realistically to objective status; the sense of control increases with education, earnings, income, employment, occupational status, job autonomy, and status of origin (Mirowsky and Ross 1989; Wheaton 1980) It declines with the frequency of undesirable events such as being laid off or fired, divorced or widowed, and sick or injured, and with the intensity of problems such as economic hardship (Pearlin et al. 1981).

Self-efficacy

When describing empowerment, researchers often include *self-efficacy*. Perceived self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affects their lives (Bandura 1997). Self-efficacy beliefs determine how people feel, think, motivate themselves and behave. Self-efficacy is one of the core elements of the empowerment process. It has been studied extensively and measured across many domains. There is a large amount of consistent evidence linking it to motivation and performance across situations and cultures (Bandura 2002; Bandura and Locke 2003). Competence is one of the other factors that is

believed to be related to self-efficacy (Bandura 1995). Competence is defined as the ability to do something successfully and efficiently. It is a combination of observable and measurable knowledge, skills, abilities and personal attributes that contribute to enhanced individual performance and ultimately result in achieving goals. Individuals who perform unsuccessfully are likely to do so not necessarily because they lack skills, but because they lack the self-efficacy belief to use skills effectively (Bandura 1997).

Self-efficacy is not the only influence on behaviour nor can it change all the behaviours of a person (Bandura 1986). Self-efficacy belief can influence the choice of activities, effort, persistence and achievement hence self-efficacy affects the behaviour of a person (Bandura 1997). For example, there is evidence that self-efficacy predicts such diverse outcomes as academic achievements, social skills, smoking cessation, pain tolerance, athletic performances, career choices, assertiveness, coping with feared events, recovery from heart attack, and sales performance (Bandura 1986; Maddux 1993; Schunk 1989).

Self-efficacy and Motivation

Self-efficacy has received increasing attention in educational research, primarily in studies of academic motivation. It relates positively to motivation to employ learning strategies (Corno and Mandinach 1983; Pintrich and Schunk 1995). (Pintrich and De Groot 1990) had seventh graders judge efficacy and use of various strategies, including effort management and persistence. Efficacy was positively related to reported strategy use. Zimmerman and Martinez-Pons (1990) had students in Grades 5, 8, and 11 judging the use of various learning strategies that included motivational components, as well as their efficacy for performing mathematical and verbal tasks. Efficacy related positively to reported strategy use across domains. (Schunk and Cox 1986) found that having learning disabled students verbalize the steps in the strategy while applying it raises motivation, self-efficacy, and skill.

Self-efficacy has relatively established a body of research showing its positive impact on work-related performance. In their study, Stajkovic and Luthens have shown a significant relationship between self-efficacy and work-related performance of the adult employees (Stajkovic and Luthens 2003). In addition to its positive impact on work performance, they have further concluded that the self-efficacy makes an important contribution to work motivation. According to Bandura's Social Cognitive Theory, individuals possess a self-system that enables them to exercise a measure of control over their thoughts, feelings, motivation, and actions (Bandura 1986). Social Cognitive Theory acknowledges that employees base their actions on both intrinsic (desires) and extrinsic (contingent consequences from the environment) motivation. However, in addition, Social Cognitive Theory posits that employees also act on their self-efficacy beliefs of how well they can perform the behaviours necessary to succeed. Thus, under Social Cognitive Theory employee behaviour cannot be fully predicted without considering his/her self-efficacy (Stajkovic and Luthens 2003).

There have been several studies to investigate the role of self-efficacy and motivation in physical activity in adult populations. Despite documentation of the physical and psychological benefits derived from regular activity, these studies show that the majority of the adult population is not involved in physical activity on a regular basis (O'Neill and Reid 1991; Schutzer and Graves 2004). In their research, Cohen-Mansfield et al observed that barriers to exercise to be highly related to the motivators and self-efficacy beliefs (Cohen-Mansfield et al. 2003). Therefore, an awareness of the cognitive processes specific to motivation and behavioural change as a result of one's personal efficacy is fundamental to understanding exercise adherence (Schutzer and Graves 2004).

Sense of control and Choices

When people work, individuals reshape the set of given choices to be personally feasible within their specific situations. Choice process theory assumes that sense of control is a consequence of exercising greater choices (Lawler 1992). To make the set of given choice opportunities more personally feasible, individuals do not remain passive, but react actively to them. Choice process involves reshaping, estimating, developing, and interpreting a set of given choice opportunities. The choice process theory indicates that this active involvement in choice processes generates sense of control beyond the objectively established set of choices (Lawler 1992).

Self-efficacy, Motivation and Locus of Control

One of the theories most often discussed in relation to self-efficacy is Julian Rotter's Locus of Control theory (Rotter 1966). Locus of control refers to people's very general, cross-situational beliefs about what determines the outcomes in their life. People can be classified along a continuum from very internal to very external. Rotter described internal locus of control as: *the degree to which people expect that a reinforcement or an outcome of their behaviour is contingent on their own behaviour and personal characteristics* (Rotter 1990). Their belief in their ability to change things may well make them more confident and they will hence seek information that will help them influence people and situations. They are also likely to become more motivated and success-oriented.

In contrast, people with high external locus of control believe that they personally have little or no control over the events of their lives. Rotter described external locus of control as: *the degree to which people expect that the reinforcement or outcome is a function of chance, luck or fate, is under the control of powerful others, or is simply unpredictable* (Rotter 1990). Therefore, they see little impact of their own efforts on the amount of

reinforcement or outcome they receive. Compared with persons who doubt their capabilities, those with high self-efficacy for accomplishing a task participate more readily, work harder, persist longer when they encounter difficulties, and achieve at a higher level. (Schunk 1995).

Rubin explored locus of control as an important psychological antecedent to how and why people communicate in interpersonal and mass-media contexts (Rubin 1993). (Schutz 1966) suggested that some interpersonal needs such as inclusion, affection and control can influence all aspects of communication between people. Results of this study showed that individual differences such as one's sense of control of his/her life clearly influence motives to communicate and dispositions to future communication. In addition it showed that the external control signifies ritualistic communication motivation, interaction avoidance, and communication dissatisfaction and internal control means finding interaction rewarding and satisfying (Rubin 1993).

A study conducted by Anderson (2005) used a novel multidimensional locus of control instrument (I-SEE) to investigate the relationship between locus of control, motivation, and academic achievement in three different types of school in New Zealand (Anderson et al. 2005). The instrument incorporates the construct of self-efficacy and includes the role of the environment and personality. The results supported the idea that locus of control is a multidimensional construct with varied internal and external values. There were statistically significant differences between schools for motivation and achievement and a mediating effect between locus of control and school type. Furthermore, results reported that moderate levels of locus of control and self-efficacy appear to be more adaptive than either extremely high or low levels (Anderson et al. 2005).

In recent health related studies, the role of the psychological attributes such as self-efficacy and locus of control have been investigated. A recent study by Roddenbury (2010)

investigated the mediating effects of locus of control and self-efficacy in the relationships among stress, illness, and the utilization of health services in a sample of 159 college students (Roddenberry and Renk 2010). Results suggested that participants who endorse higher levels of stress also endorse higher levels of illness, higher levels of external locus of control, and lower levels of self-efficacy. In addition, structural equation modelling suggests that there are direct relationships between stress and illness and between illness and the utilization of health services. Further, locus of control appears to be a partial mediator in the relationship between stress and illness.

Self-efficacy and health locus of control have been positively related in health-related behaviours in older adults (Waller and Bates 1992). One of the health-related behaviours such as nutritional behaviour, is strongly predicted by self-efficacy (Greene et al. 2004). Chen (2010) conducted a study to examine the relationships among selected demographic characteristics, nutrition self-efficacy, health locus of control and nutritional status in older Taiwanese adults (Chen et al. 2010). As (Bandura 1989) suggested, the results of this study did not indicate stronger beliefs of capabilities leading to more persistent and greater efforts. In contrast to other studies, it did not show that self-efficacy was a good predictor of health behaviour and nutritional outcomes (Chen 1999; Greene et al. 2004). Authors suggested that further research need to be performed in areas of ageing process and culture to understand these results (Chen et al. 2010).

2.3.3 Relationships between Psychological empowerment and its enablers

Drawing the literature together, we have created a conceptual model of psychological empowerment as shown in Figure 2-3 below.

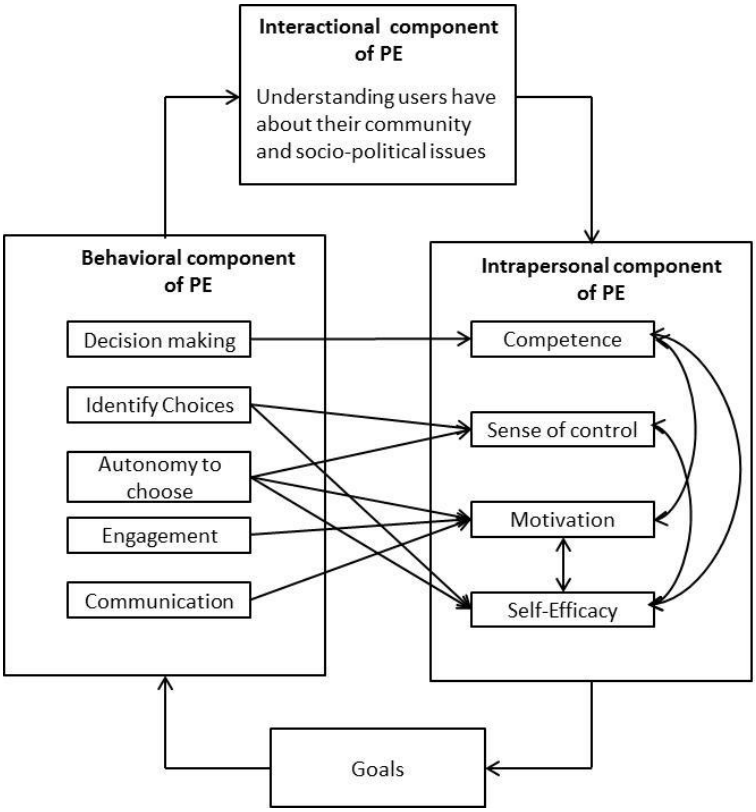

Figure 2-3 : A Conceptual Model of Psychological Empowerment

It shows the three components of psychological empowerment (i.e. interactional, behavioural and interpersonal), the four empowerment outcomes (i.e. competence, sense of control, motivation and self-efficacy), the key drivers and influencers (i.e. decision making, choices, autonomy, engagement, communication and meaningful personal goals) and their relationships to each other. Some factors are bidirectional as they may influence an empowerment outcome, but also change as empowerment level changes. The empowerment outcome will be influenced by the actions taken by the user due to these drivers. For example, when the users have access to different types of knowledge and information, they can make informed decisions and become competent. Further, with the access to knowledge and data in context, users can identify the choices and the barriers they may have. When exercising greater choices, users gain a sense of control of their lives, become more engaged, motivated to gain new experiences and believe that they have

necessary skills to achieve goals in their lives. Zimmerman (1995) suggests that the skills of users that are enhanced by the processes and structures provide them with the support to make necessary changes at the community level too (Zimmerman 1995).

2.4 Applications to support empowerment

Empowerment is studied across many areas such as psychology, community development, education, social studies, and organisations among others (Perkins and Zimmerman 1995; Rapport 1987; Zimmerman 1988; Zimmerman 2000). As a result, many applications have been developed to empower users in these areas.

For example, (Li et al. 2012) have carried out a feasibility study to create an Online Advisory System (OAS) to empower victims of domestic violence (DV). It examines the practical and conceptual challenges faced when helping emotionally stressed DV victims to make life changing decisions of their lives. The design of the prototype uses both trans-theoretical model and empowerment theory. It provides DV victims with anonymous online access via the OAS and personalised information needs and support in the early stages of domestic violence cycle. One of the major benefits of an online DV tool is the improved access to information such as contact details of local professionals, personal experience of others and expert advice. (Li et al. 2012). Breaking out of an abusive relationship depends on the action a victim takes but an OAS provides the victim at least some choices.

In healthcare systems *patient empowerment* is a term that has been in use for a long time. There is numerous numbers of applications that have been developed in healthcare to address diverse areas of health. The *Learning Health System* is designed to deliver personalized healthcare information and support shared decision making with providers. In addition, it aims to provide knowledge generated from patients' experience across the groups. This learned knowledge will be the key to empowering patients in the *Learning*

Health System (Kumar et al. 2015). In another application called *Intelligent Health Information System*, semantic Web technologies are utilized to keep patients informed on the latest research on chronic diseases such as diabetes, by gathering online information published by both government and corporate sources. This information is stored on the diabetes ontology. The application searched for articles on diabetes using a web service and a web crawler. *Intelligent Health Information System* synthesizes the information that it gathers, make it customer-specific, and present it to the patient in an easy to understand format. (Islam et al. 2012). *EMPOWER* is web/mobile based platform which aims at supporting self-management activities of diabetes patients and their treating physicians in Germany and Turkey. The platform semantically integrates multiple information sources, such as electronic and personal health records. Patients can register patterns of daily living, record blood glucose levels, design disease management plans and set long- and short-term goals. The project actively involves the treating physician, who has the possibility to set recommendations for the patient and to monitor his/her progress on the platform (Mantwill et al. 2015).

Education is another area where there are number of applications that have been developed to empower the students. The *Get Set for Success* quiz was developed across five Australian institutions to enable commencing first year engineering students to self-test their readiness to study their chosen degree. The quiz comprises two parts. Part 1 measures cognitive abilities (i.e., maths, physics and chemistry) and Part 2 measures non-cognitive factors (i.e., approaches to learning and motivations for study). Both parts have been shown to predict academic success. Individualised feedback was provided to students enrolled in engineering technology and applied science courses at the University of New England, a regional Australian university that directed students to both on campus and online support to help them develop an individual study plan to address knowledge and skills gaps. This approach helps to empower students to begin their academic journey

with confidence – it enables them to reflect on their approaches to learning and to seek support to address any identified gaps. (Wilkes and Burton 2015).

2.4.1 Current mobile-based agricultural solutions in developing countries

Though mobile broadband is the future, in East Africa, voice and SMS are the most common applications that are used today. SMS text messaging projects with a partnership with a mobile service provider has allowed wider coverage of services in this region. *DrumNet* (Kopicki and Miller 2008), *SMS Sokoni* (KACE 2015) and *RATIN SMS* (RATIN 2015) projects in Kenya, *eSoko* project in Rwanda (eSoko 2015) and *FOODNET* (FOODNET 1999) project in Uganda use text messaging service to link farmers to various markets to receive commodity prices, finances and information. In Uganda, there are projects that use SMS-based keyword search to provide location and contact details of shops offering specific agriculture inputs such as seeds, pesticides and fertiliser, and menu guided keyword search to provide agronomic techniques for coffee and banana production (Grameen 2002). INFOTRADE Mobile is a project that was developed in Uganda that provides up-to-date agricultural prices for the queries from the farmers (INFOTRADE 2008). The ICT Sector Unit of the World Bank has done a detailed study of mobile applications available in Kenya, the Philippines and Sri Lanka and their impact (Qiang et al. 2011). These applications focus on improving agriculture supply chain integration and have a wide range of functions, such as providing market information, increasing access to extension services and facilitating market links. In addition to above, there have been many other successful mobile applications to support the farmers in developing countries including: e-Choupal project in India that delivers farming information to farmers' mobile phones (Radhakrishna 2011), 8villages business project in Indonesia that delivers information to farmer's mobiles using the social network concept (Vaswani 2012), and Rural and Agricultural Development Communication Network (RADCON) project in Egypt

that uses an interactive community-based information network to help meet the information and communication needs of rural farmers (UNICEF 2011).

Table 2-1 below shows a summary of some mobile applications used in developing countries. They are categorised in to three sections; extension and knowledge systems, market information systems and procurement.

Table 2-1 : Mobile applications in developing countries

Application	Modality	Category	Description
M-Farm (mfarms 2013)	SMS and Interactive Voice Recordings	Market information	With over 7,000 registered users *M-Farm* updates farmers on current prices of goods across Kenya. It provides a networking platform to connect to other farmers in order to sell their goods in larger quantities. The app also connects local farmers directly to suppliers without middle men and gives significant discounts on fertilizers and seeds.
DrumNet (DrumNet 2005)	SMS	Procurement and traceability	Originally a project of PRIDE AFRICA, the *DrumNet* organization in Africa is emerging as a network of support centers that provide on-the-ground assistance through the delivery of a range of financial, marketing, and information products and services. The overall objective of the program is to provide poor farmers with improved access to new agricultural technology, markets, financial and non-financial information and a bridge to the formal financial system to grow and diversify their businesses, generate more income and employment as well as creating forward-backward linkages.

Application	Modality	Category	Description
Esoko (eSoko 2015)	SMS	Market information	*eSoko* project in Rwanda connects projects, Non-Governmental Organizations (NGO), businesses and government to farmers. Currently operating in nine countries across Africa, *Esoko* formerly known as TradeNet, provides agricultural content, marketing, advisory and monitoring services for farmers and potential investors.
Agro-Hub (Agro-Hub 2015)	SMS	Extension and knowledge systems	*Agro-Hub* explores joint community effort, SMS and the internet to source, manage and disseminate information on anything pertaining to agriculture.
Farming Instructor (VC4A 2012)	SMS	Extension and knowledge systems	*Farming Instructor* is a mobile application that provides online and offline agricultural information (text, speeches and animations) to farmers and their communities in the world (ict4ag 2013). The application is created specifically to inspire youth and all other groups in the society to have the passion to engage in agriculture as the means to self-employment. With this application, the user or farmer is be able to get all the necessary information related to agriculture as well as be able to share and comment on other farming tips they know.
Cocoa Link (CocoaLink 2011)	SMS and voice recordings	Extension and knowledge systems	*CocoaLink* is a mobile technology application that delivers practical information from agricultural experts to farmers in English and local languages at no cost. This technology is available in Ghana, the world's second largest cocoa producer, and has over 100,000 users.

Application	Modality	Category	Description
Kace (KACE 2015)	SMS	Market Information	Kenya Agricultural Commodity Exchange *(KACE)* is a private sector firm based in Kenya, whose objective is to provide reliable and timely market information to both buyers and sellers of agricultural commodities. It links farmers and traders for business in agricultural commodities, whereby KACE members of staff collect daily information on the prices of various commodities from market vendors in Nairobi, Bungoma, Machakos, Kisii, Kisumu, Mumias and Eldoret, among other towns in the country.
Kilimo Salama (Salama 2010)	SMS	Extension and knowledge systems	*Kilimo Salama* in Kenya provides farmers with up-to-date and full climate data via text message. Farmers that are connected to this application also receive information on ways to increase productivity, ensure food security and also protect their crops during bad weather.
mKrishi (mKrishi 2012)	Voice , SMS & Image uploading facility	Extension and knowledge systems/Market Information	*mKrishi* mobile application developed in India connects farming communities and provides personalized agriculture advice and market information.
Kuza Doctor	SMS	Extension and knowledge systems	This application enables farmers to receive specific information on crop growth, soil and other general questions through SMS. Created by the farmers in Kenya, the application is supposed to help farmers grow better crops by employing environment-friendly techniques.
Foodnet (FOODNET 2004)	SMS and voice	Market information	*FOODNET*'s market information services in Uganda, currently reach over 7 million people each week. The national market information service is run by FOODNET in association with the Ministry of Trade, Tourism and Industry. One of the services it provides is to the farmers with commodity prices that can be accessed via the mobile phones.

Application	Modality	Category	Description
VetAfrica (VetAfrica 2014)	Cloud Software	Knowledge systems	*VetAfrica*, allows both farmers and veterinarians to diagnose livestock on the spot, receive information on proper medication to be administered, and share information through cloud software so that illnesses can be tracked and monitored across each area.
m-Omulimisa (m-omulimisa 2014)	SMS	Extension and Knowledge systems	*m-Omulimisia* provides smallholder farmers in Uganda with real-time farming information and solutions written in local languages via mobile technologies. Farmers can use their phones to ask questions in languages that they understand, and receive understandable feedback from extension officers in the region via text messages. Registered farmers also receive location-based information of weather, markets, and best farming practice regularly from extension officers.
WeFarm (WeFarm 2017)	SMS	Knowledge Systems	*WeFarm* is a peer-to-peer (P2P) knowledge sharing platform for small-scale farmers in rural communities of Kenya, Uganda and Peru. It allows farmers to ask questions via SMS short codes and receive answers from other registered users. The platform is open to anyone, including experts and those wishing to do business with farmers, and is available in both English and Swahili.

Application	Modality	Category	Description
321online (321online 2015)	Voice	Knowledge Systems	*321online* application is used in Malawi and Madagascar which provides access to a range of information including agriculture on users' mobile phones by voice message in local languages. The users can dial the toll-free number, 3-2-1, anytime, anywhere. They are greeted by a welcome message in their local language. The voice prompts them through the menu of topics until they find the trusted information they need. The content of the messages is created by experts and is validated by government officials.
FarmerLink (FarmerLink 2016)	SMS		*FarmerLink* is a mobile solution created by the Grameen Foundation for the coconut farmers in the Philippines. FarmerLink combines satellite data and farm data collected by mobile equipped field agents to help coconut farmers increase productivity, deal with crop pests and diseases, and increase the sustainability of their farms.
KrishiSuchak (KrishiSuchak 2015)	SMS	Extension and Knowledge systems	*KrishiSuchak* is a WhatsApp-like app developed in Bangalore. It permits smallholders to message agricultural scientist to ask them for advice on their yields, thus eliminating spatial barriers between extension services. Farmers can send their queries either as text, a photo or a record of their voices to the extension officers.

Application	Modality	Category	Description
RevoFarm (RevoFarm 2016)	SMS	Knowledge systems	*RevoFarm* is a Jamaican based app designed to connect farmers to markets and market data. Farmers send an SMS with their available crops and the information is uploaded on the website. Consumers, which can also include supermarkets who want fresh produce from farmers, can then search the RevoFarm marketplace (on the website or on the app) and find fresh farm produce closest to them.
iCow (iCow 2010)	SMS	Extension and Knowledge systems	*iCow* is a comprehensive solution for farmers in Kenya, Tanzania, Ethiopia to support them with livestock and crop production and to connect farmers to the vital players in their agricultural ecosystem. These include input providers, agricultural financial service providers, veterinary experts, agricultural extension service providers, NGO's. It is designed for the most basic feature phones and is available in different languages depending on the county of deployment.
ECAMIC (ECAMIC 2012)	SMS	Market information	The *ECAMIC* project uses the Esoko platform, a trading platform using internet and mobile phones. This platform is used to send offers on produce and alerts of district market prices to the farmers via SMS.

2.4.2 Knowledge gap in current mobile-based agricultural solutions in developing countries

Undoubtedly, these successful projects discussed in section 2.4.1 enhance some sections of the supply chain of farming and bring many economic and social benefits. Projects like above focus on one or two stages of a whole farming life cycle. When information on good cultivation practices or pest and disease management is provided, it helps *seeding stage, and preparing and planting stage* of the farming cycle only. In a complete farming cycle however, there can be as many as six stages that have different information needs and activities (De Silva and Ratnadiwakara 2010). Understanding the current market prices is important but *selling stage* is one of the final stages of a farming cycle. To benefit from the market prices, a farmer needs to produce a successful yield first. This means when providing information, the holistic approach should be adopted to cater for information needs of all the stages of a crop cycle.

Further, the importance of developing collaborative and innovative applications was identified in (Poulson 2016). In the conclusion of Sida Review 2012 report, it has identified the trend of how East African users are moving from traditional voice/SMS usage to data and IP (from 2G, to 3G and 4G mobile standards). With regards to appliance innovation and application development, Sida Review recommends promoting collaboration by using the features of Web 2.0 applications (Hellström 2010).

Most of the current agriculture mobile solutions are designed for the farmers to receive a small sub-set of required information in a passive mode. None of the projects identified above explicitly address empowerment or how to motivate the targeted users to utilise the technology to its full potential. For example, current mobile applications have no provision for the farmers to share, collaborate and make informed decisions.

2.5 Summary

This chapter presented the current theories and applications that are related to the main aim as described in chapter 1. This review identified the knowledge gap in the current mobile-based agricultural solutions available for the farmers in the developing countries.

3 Research Methodology

Chapter 1 introduced the broader context of the problem definition and research objectives of the overall collaborative project. As stated in section 1.4, the aim of this study was to *develop and validate an empowerment framework for developing mobile-based applications to empower users in their livelihood activities*.

In chapter 2, a detailed review of related work, the importance of addressing identified research question and gaps in current agriculture mobile-based solutions were presented. The objective of this chapter is to present the research approach that was employed to conduct this research.

This chapter is organised as follows; first, the research questions and characteristics of the problem domain are discussed. Then the selected research methodology, the Design Science Research (DSR) paradigm is explained along with the research plan and the main research cycles.

3.1 Aim and Research Questions

Aim: Develop and validate an empowerment framework for developing mobile-based applications to empower users in their livelihood activities.

3.1.1 Research Questions

To address the aim of the research, it was narrowed to a particular type of users, which is farmers, and three main research questions; RQ1, RQ2 and RQ3, were formulated. Each research question was divided again in to several other sub-questions as shown in the Table 3-1 below.

Table 3-1 : Research Questions

Research Question 1(RQ1): How can farmers be empowered in their livelihood activities?	Research Question 2 (RQ2): How to design a suitable Mobile-based Information System (MBIS) to empower farmers?	Research Question (RQ3): How to evaluate the effectiveness of the empowerment framework?
RQ1.1 What are the goals of farmers and the opportunities and obstacles they have to achieve these goals? RQ1.2 What is a suitable working definition for empowerment in the context of Sri Lankan farmers? RQ 1.3 What is an initial conceptual empowerment model for Sri Lankan farmers? RQ 1.4 How can technology be used to empower farmers: stage 1 – Initial investigation RQ 1.5 How can technology can be used to empower farmers: Stage 2 – Enhancing profit calculator RQ 1.6 How do farmers make decisions?	RQ2.1 –What are the elements of an empowerment framework? RQ2.2 – What is a refined empowerment model for the Sri Lankan farmers? RQ2.3 – How can choice be implemented in empowerment processes? RQ2.4 – How can the overall MBIS be designed with respect to empowerment?	RQ3.1 What instruments can be used to evaluate the empowerment? RQ3.2 How can pre and post MBIS responses of the farmers be analysed?

3.1.2 Research Question 1(RQ1): How can farmers be empowered in their livelihood activities?

The main objective of this research question 1 was to find out the elements of the empowerment framework by studying specific instances of farmer empowerment. Therefore, to find the answers to this question, we needed to carry out our investigation in several areas. First it was necessary to understand the goals of the farmers and the opportunities they have, and the obstacles they face in the agriculture environment. As this research focusses on empowerment, we then concentrated on understanding the concepts underpinning empowerment theory, psychological empowerment, key drivers of empowerment and their relationship to each other. With the goals of the farmers, the concepts of empowerment theory and the objective of this study in mind, we then developed a definition of empowerment in the context of the Sri Lankan farmers. These concepts and ideas have helped us to create an initial conceptual empowerment model to represent the goals of the farmers, empowerment processes and empowerment outcomes. In addition, this study further investigated how technology can be used to empower the farmers and how farmers were making decisions prior to the introduction of the mobile artefact.

3.1.3 Research Question 2 (RQ2): How to design a suitable Mobile Based Information System (MBIS) to empower farmers?

From the insights that were gained at the end of the investigation of RQ1, the elements of an empowerment framework were identified. Based on the existing empowerment theory and these identified elements, we defined an empowerment framework. Therefore, in this research question, we discuss how the mobile-based information system was designed based on the empowerment framework.

3.1.4 Research Question (RQ3): How to evaluate the effectiveness of the empowerment framework?

The success of the artefact to empower the users reflects the effectiveness of the framework. Therefore, in this research question, we discuss how the suitable instruments were designed to capture the necessary data and how this data was analysed to measure the impact of the artefact on the empowerment levels of the farmers.

3.2 Knowledge of the research environment prior to the commencement of research:

The aim of this research was to *develop and validate an empowerment framework that can be used to develop mobile-based applications which empower users in their livelihood activities*. Before beginning the research, it was necessary to understand the environment in which the users operated. Therefore, in this study, the characteristics of organisational systems, people, problems and opportunities were investigated to better understand the research problem.

3.2.1 Characteristics of Farmers in our Study

Farmers in our study were experienced in farming and made their decisions based on their experience (Lokanathan and Kapugama 2012; Nadeeshani and Broekel 2015). In some situations, the information they used for their decision making was not accurate, up-to-date or complete. Prior to our research, farmers have experienced interventions by other local and international organisations to improve their livelihood. Though these programs assisted some aspects of their farming, most programs were discontinued due to lack of funds. The farmers, therefore, at the beginning, were apprehensive about working with this research project.

3.2.2 Characteristics of Researchers

The collaborative research group were well-versed in information technology but not in the agriculture domain. Therefore, at the beginning of this research, it was a challenge for

the researchers to understand the stages and business processes relevant to the farming domain and the dynamics of the highly politicised agriculture sector in Sri Lanka.

3.3 Research methodology overview

Research methodology is a term that describes the strategy of inquiry used to answer a specific research question. Essentially, the procedures by which researchers go about their work of describing, explaining and predicting phenomena are called a research methodology. It is also defined as the study of methods by which knowledge is gained. Its aim is to provide a work plan for a research project (Creswell 2009; Rajasekar et al. 2013). Currently there are four main strategies of inquiry: quantitative, qualitative, mixed and design science (Creswell 2009; Hevner et al. 2004; Recker 2013, p36).

Quantitative strategies are procedures that feature methods such as experiments or surveys and they are characterised by an emphasis on quantitative data. These procedures have a focus on numbers and measured values. Qualitative strategies are procedures that feature research methods such as case studies, ethnography or phenomenology and which are characterised by an emphasis on qualitative data. In qualitative procedures, the main focus is on words. Mixed methods are procedures that feature combinations of both qualitative and quantitative strategies in either sequential or concurrent fashion. The main focus in these procedures is on both numbers and words.

Design Science Methods are procedures that feature methods to build and evaluate novel and innovative artefacts such as new models, methods or systems, as the outcome of a research process. These procedures are characterised by an emphasis on the construction of an artefact and the demonstration of its utility to a group or an organisational or societal problem.

The selection of an appropriate strategy of inquiry to determine the research methodology is critical to the success of any research project and must be driven by the research question as well as the current state of knowledge in the area being studied.

3.4 Selecting an appropriate research methodology:

When selecting an appropriate research methodology for this research, the following important factors were considered.

a) Type of technology used
b) Nature of the research problem

3.4.1 Type of technology used

To promote ICT access and service in Sri Lanka, a project called e-Sri Lanka was established in 2013 (Nenasala 2013). Projects like this have increased the awareness of computer literacy and skills in the knowledge-based economy in Sri Lanka. Though digital literacy has gradually increased in Sri Lanka, it is lower in rural areas of the country. One of the reasons for this is the high purchasing and maintenance costs of personal computers. Learning how to use a computer has a high learning curve. Another reason is a lack of supporting literacy programs in rural areas. In addition, the software available for different applications is often not compatible with the native languages. These factors discourage lower-income families from using personal computers and limit their access to information. Therefore, when deciding on a type of the technology to use for this research, it was clear that a computer based solution was not the most appropriate for farmers (Lanka 2015). As a result, the researchers decided to adopt a mobile-based solution. The following discussion provides other reasons in support for a mobile-based solution.

Since 2000, Sri Lanka has a rapid growth of mobile penetration (ITU 2015). According to ITU (2015), at the end of 2014, 98.6% of the population in the country had a mobile-cellular telephone subscription. Another supporting factor to adopt a mobile-based solution was the affordability of internet connectivity with cheapest broadband connections priced at just under US$5 a month (DailyFT 2014). Increasingly affordable handsets and data packages have boosted mobile internet use, particularly among young people (Sirimanna 2013). In the third quarter of 2014, Sri Lanka's mobile phone imports reached 1 million units, while the shipments of smartphones increased by 100 percent compared to the second quarter (LBO 2014). The overall growth rate for the market has been consistent year after year, which has in turn contributed to an increase in the use of smartphones to access the internet. At present, it is estimated that over 20 percent of the population of Sri Lanka use smart devices (LBO 2014). Monthly subscriptions for mobile data packages can run as low as US$3 a month. Based on these data, the researchers have decided to create an information system that can be accessed using smart devices.

3.4.2 Nature of the research problem

Though farmers in Sri Lanka have many years of experience in farming, except for the television and radio, they had not been using technology to obtain information to support their livelihood activities. They have used normal mobile phones that do not have the advanced capabilities of a smart phone in their daily communications. Therefore, the decision to use smart technology to introduce a technological solution presented some challenges. Most of the farmers were new to smart phone technology and had not seen or used agricultural mobile applications on a smart phone. Therefore, they had difficulty envisaging how this new technology could help them. They were unable to clearly define their user requirements.

The research team had a clear vision and a solid sense of direction of the overall research project. However, as the problem had the characteristics of an ill-structured problem and the user requirements were unclear, the researchers decided to use an adaptive software development approach (Highsmith 2013). This is an iterative process of learning, implementing and evaluating. At each evaluation, feedback was received and a new set of requirements added. They were considered as opportunities for learning and achieving the goals of the project.

3.5 Selected research methodology

After considering the issues discussed in section 3.4, Design Science Research (DSR) was chosen as the most appropriate research methodology for this study. The main aim of this research project was to *develop and validate an empowerment framework that can be used to develop mobile-based applications which empower users in their livelihood activities*. The motivation and desire of this research was to empower the Sri Lankan farmers by providing them with a new and an innovative artefact that can enable them to make informed decision making to improve their livelihoods. DSR provides a framework to design such innovative artefacts that define ideas, practices, technical capabilities and products. Further, the DSR process assists the analysis, design, implementation and the use of information systems that can be effectively and efficiently accomplished (Hevner et al. 2004).

DSR in information systems can address problems that are considered to be wicked problems (Brooks 1996; Rittel and Weber 1984). These wicked problems can be characterised as ill-structured problems. They usually lack the structure of an existing state and a desired state (Simon 1973). Though it is difficult to clearly define and explain ill-structured problems, this research problem represented some characteristics of an ill-structured problem (see section 3.2). Agriculture is an important sector in Sri Lanka with

many sub divisions and complex interactions between them. At the beginning of this research, it was difficult to understand these interactions clearly and how the sub-divisions functioned as a whole. It was decided that DSR can be used to address this type of problems which can be characterised by unstable and unclear requirements and constraints based on ill-defined environmental contexts, and complex interactions among subcomponents of a problem (Hevner et al. 2004; Rittel 1973).

3.6 Design Science Research

Design Science research is a constructive research method in that it produces an innovative artefact as its constitutive and distinctive research output (Hevner et al. 2004; Livari 2015; Recker 2013, p36).

Design Science research has been defined as

> *a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artefacts, thereby contributing new knowledge to the body of scientific evidence. The designed artefacts are both useful and fundamental in understanding that problem* (Hevner and Chatterjee 2010, p5).

There has been increasing interest in design science research in information systems (IS) discipline (Hevner and Chatterjee 2010; Hevner et al. 2004; Livari 2007; March and Smith 1995; Nunamaker et al. 1990-1991; Peffers et al. 2007-2008; Vaishnavi and Kuechler 2008; Walls and Widmeyer 1992).

Design Science Research is said to stem from a desire to complement mainstream behavioural orientation of information systems research with a more design-oriented approach. It has its roots in engineering and the sciences of the artificial intelligence (Simon 1996). It is fundamentally a problem-solving paradigm. Design Science Research encompasses the idea that doing innovative design that results in clear contributions to

the knowledge base constitutes research. Design science research projects are often performed in a specific application context and the resulting designs and design research contributions may be clearly influenced by the opportunities and constraints of the application domain.

3.6.1 Artefact

The fundamental principle of design science research is therefore that knowledge and understanding of a design problem and its solution are acquired in the building and application of an artefact. The term artefact is central to design science research and is used to describe something that is artificial, or constructed by humans, as opposed to something that occurs naturally. In design science, as a research activity, the interest is on artefacts that improve upon existing solutions to a problem or perhaps provide a first solution to an important problem. At least five types of artefacts are typically identified:

a) Constructs (vocabulary and symbols)
b) Models (abstractions and representations)
c) Methods (algorithms and practices)
d) Instantiations (implemented and prototype systems)
e) Design theories (improved models of design, or design processes) (Hevner et al. 2004)

3.6.2 Design Science Research Framework

Figure 3-1 shows a design science framework in which such artefacts can be developed. This framework is bounded by the practical environment and the available knowledge base at that point in time.

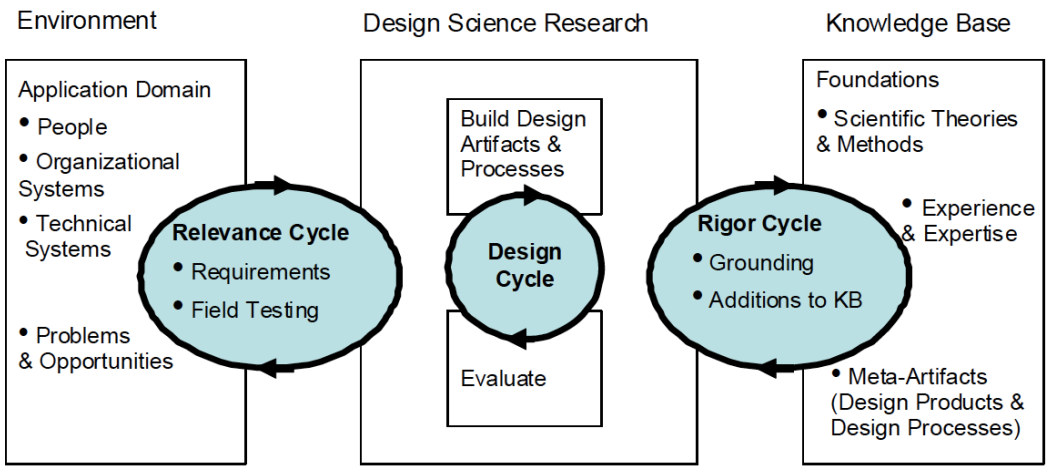

Figure 3-1: Design Science Research framework (Hevner et al. 2004)

The *environment* defines the problem space in which the phenomena of interest reside. In information systems research, the environment is comprised at least of people, organisational structures, and technologies. It thereby establishes the relevance of design science research. The *knowledge base* provides the materials from and through which design science research is accomplished. That is, prior research and results from relevant disciplines provide foundational theories, frameworks, instruments, constructs, models, methods, and instantiations that can be used in the design phase. The *knowledge base* therefore assists the design science in achieving rigor. Design science research is comprised of activities related to building and evaluating artefacts designed to meet the identified business needs. The *relevance cycle* bridges the contextual environment of the research project with the design science activities. The *rigor cycle* connects the design science activities with the knowledge base of scientific foundations, experience, and expertise that informs the research project. The central *design cycle* iterates between the core activities of building and evaluating the design artefacts and processes of the research. In a design science research project , these three cycles must be present and clearly identifiable (Hevner 2007).

3.6.3 The Relevance Cycle

Design Science Research is motivated by the desire to improve the environment by developing new and innovative artefacts and the processes for building these artefacts (Simon 1973). An application domain consists of the people, organisational systems, and technical systems that interact to work toward a goal. Good design science research often begins by identifying and representing opportunities and problems in an actual application environment. In addition, the relevance cycle defines acceptance criteria for the ultimate evaluation of research results such as; does the design artefact improve the environment and how it can be measured. The output from design science research must be returned to the environment for study and evaluation in the application domain (Cole et al. 2005). The results of the field testing will determine whether additional iterations of the relevance cycle are needed.

3.6.4 The Rigor Cycle

Design science draws from a vast knowledge base of scientific theories and engineering methods that provide the foundation for rigorous design science research. The knowledge base contains knowledge of:

a) The experiences and expertise that define the state of the art in the application domain of the research.
b) The existing artefacts and processes found in the application domain (Iivari 2007).

The rigor cycle provides past knowledge to the research project to ensure its innovation. It is contingent on the researchers to thoroughly research and reference the knowledge base to guarantee that the designs produced are research contributions. Consideration of rigor in design research is based on the researcher's skilled selection and application of appropriate theories and methods for constructing and evaluating the artefact. Design science research is grounded on existing ideas drawn from the domain knowledge base.

Inspiration for creative design activity can be drawn from many different sources to include rich opportunities/problems from the application environment, existing artefacts, analogies/metaphors, and theories (Iivari 2007).

Additions to the knowledge base, as results of design research, will include any additions or extensions to the original theories and methods made during the research, the new artefacts (design products and processes), and all experiences gained from performing the iterative design cycles and field testing the artefact in the application environment.

3.6.5 The Design Cycle

The internal design cycle is the heart of any design science research project. This cycle of research activities iterates more rapidly between construction of an artefact, its evaluation, and subsequent feedback to refine the design further. Simon (1996) describes the nature of this cycle as generating design alternatives and evaluating the alternatives against requirements until a satisfactory design is achieved (Simon 1996). The requirements are input from the relevance cycle while the design and evaluation theories and methods are drawn from the rigor cycle. However, the design cycle is where the hard work of design science research is done.

It is important to understand the dependencies of the design cycle on the other two cycles while appreciating its relative independence during the actual execution of the research. During the performance of the design cycle a balance must be maintained between the efforts spent in constructing and evaluating the evolving design artefact. Having a strong grounded argument for the construction of the artefact is insufficient if the subsequent evaluation is weak. Iivari (2007) states, "*the essence of Information Systems as design science lies in the scientific evaluation of artefacts*" (Iivari 2007). Artefacts must be rigorously and thoroughly tested in laboratory and experimental situations before releasing them into field testing along the relevance cycle. This calls for multiple iterations

of the design cycle in design science research before contributions are output into the relevance cycle and the rigor cycle.

3.7 Design Science Research Guidelines

As shown Table 3-2, the design, implementation and evaluation of the artifact of this study were led by a clear set of the DSR guidelines (Hevner and Chatterjee 2010).

Table 3-2 : DSR Guidelines

Guideline	Description
Guideline 1: Design as an Artifact	Design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation
Guideline 2: Problem relevance	The objective of design science research is to develop technology-based solutions to important and relevant business problems
Guideline 3: Design evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods
Guideline 4: Research contributions	Effective design science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies
Guideline 5: Research rigor	Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact
Guideline 6: Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment
Guideline 7: Communication of research	Design science research must be presented effectively to both technology-oriented and management-oriented audiences

3.8 Creation of DSR sub-cycles

As discussed in section 3.6, the issues and challenges in the agriculture domain are complex. Therefore, members of the 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.

The activities in each DSR cycle can be divided in to two sub-cycles. In this complex project, each of these sub-cycles did not happen at the same time or the location. Therefore, it was important to clearly identify each sub-cycle of each DSR cycle.

The Relevance cycle was divided into two sub cycles: "Relevance – Understanding the problem" and "Relevance – suitability validation". In *Relevance – Understanding the problem* sub-cycle, the problem, opportunities and obstacles that existed in the agriculture domain were clearly identified. When a solution was designed and tested for an immediate goal, its suitability was validated in "*Relevance – suitability validation*" sub-cycle. This was an iterative process.

Relevance Cycle	Relevance – Understanding the problem
	Relevance – Suitability validation

Figure 3-2: Sub cycles of the Relevance cycle

The Design cycle was split into two sub-cycles: "Design - Heuristic Search" and "Design - Functional Validation". In *Design-Heuristic Search* sub-cycle, when a good design for an immediate goal was identified, it was designed and implemented. In this sub-cycle, various heuristic search methods were applied to design a good artefact. In *Design - Functional Validation* sub-cycle, the research team evaluated its functional validity. The constructed artefact was iterated many times between these two sub-cycles to confirm its functional validity and to produce an error free artefact.

Design Cycle	Design – Heuristic Search
	Design – Functional validation

Figure 3-3 : Sub-cycles of the Design Cycle

The Rigor cycle was split in to "Rigor – Learning" and "Rigor –Contribution" sub-cycles. Learning through the literature review process by referring to the existing artefacts, foundations and methodologies in the knowledge-base, happened in the *Rigor – Learning* sub-cycle. All new knowledge gained was contributed back to the knowledge-base in the *Rigor –Contribution* sub-cycle.

Rigor Cycle	Rigor– Learning
	Rigor – Contribution

Figure 3-4 : Sub-cycles of the Rigor cycle

The interactions among these sub-cycles are shown in Figure 3-5 below.

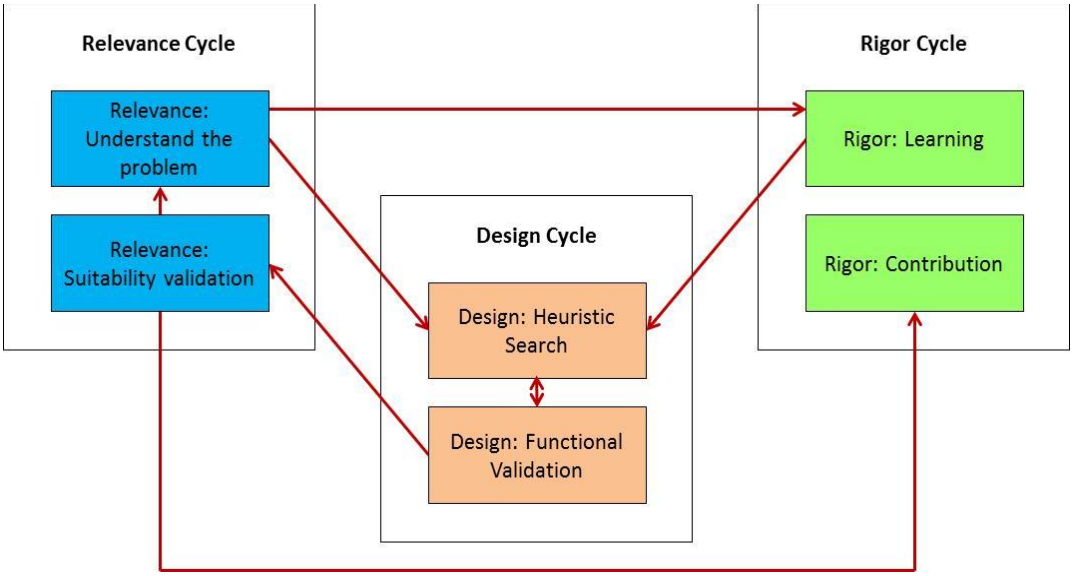

Figure 3-5 : Interactions among DSR sub-cycles

3.9 Role of DSR sub-cycles in research questions

Table 3-3, Table 3-4 and Table 3-5 below represent the role of each DSR sub-cycle employed and methods/techniques used in this investigation. There were several iterations through these sub-cycles to design the mobile artefact to empower farmers.

Table 3-3: DSR sub-cycles of RQ1 and method/technique used

Research Question 1 (RQ1)	Method/technique used in DSR sub-cycle
RQ1: How can farmers be empowered in their livelihood activities?	
RQ 1.1 What are the goals of farmers and the opportunities and obstacles they have to achieve these goals?	Relevance -understanding the problem (1) Scenario-based approach
RQ 1.2 What is a suitable working definition for empowerment in the context of Sri Lankan farmers?	Rigor – Learning (1) Related literature review
RQ 1.3 What is an initial conceptual empowerment model for Sri Lankan farmers?	Design – heuristic search (1) Exploration of possible designs and identifying a suitable one
RQ 1.4 How can technology be used to empower farmers: stage 1 – Initial investigation?	Rigor – Learning (2) Causal analysis
	Design – heuristic search (2) Exploration of possible designs and identifying a suitable one
	Design – functional validation (1) Testing and correcting errors of the design
	Relevance – suitability validation (1) Questionnaire, Field trial
RQ 1.5 How can technology be used to empower farmers: Stage 2 – Enhancing profit calculator	Relevance – Understanding the problem (2) Related literature review
RQ 1.6 How do farmers make decisions?	Relevance -understanding the problem (3) Questionnaire, Field trial

Table 3-4: DSR sub-cycles of RQ2 and method/technique used

Research Question 2 (RQ2)	Method/technique used in DSR sub-cycle
RQ2: How to design a suitable MBIS (artefact) to empower farmers?	
RQ2.1 –What are the elements of an empowerment framework? a) What are the empowerment processes? b) How to enhance decision making in the empowerment processes? c) What are the different types of knowledge required to support decision making?	Rigor – Learning (3) Related literature review
	Design – Heuristic search (3) Exploration of possible designs and identifying a suitable one
RQ2.2 – What is an enhanced empowerment model for the Sri Lankan farmers?	Design – Heuristic search (4) Exploration of possible designs and identifying a suitable one
RQ2.3 – How to implement choice in empowerment processes?	Rigor – Learning (4) Related literature review
	Design – Heuristic search (5) Exploration of possible designs and identifying a suitable one
RQ2.4 – How to design the MBIS?	Design – Heuristic search (6) Exploration of possible designs and identifying a suitable one

Table 3-5: DSR sub-cycles of RQ3 and Method/technique used

Research Question 3 (RQ3)	Method/technique used in DSR sub-cycle
RQ3: How to evaluate the effectiveness of the empowerment framework?	
RQ3.1 – What are suitable instruments to evaluate the empowerment?	Rigor – Learning (5) Related literature review
	Design – Heuristic search (7) Exploration of possible designs and identifying a suitable one
RQ3.2 – How to analyse responses of the farmers, pre and post MBIS?	Rigor – Learning (6) Related literature review
	Relevance – Suitability validation (2) Questionnaire, Field trial (Part 1 – deployment and data gathering prior to MBIS, Part 2 – data gathering after MBIS)

3.10 Ethics Approval and Data Security

All activities and data collection discussed in this and subsequent chapters were done following approval of the Macquarie University Human Ethics Research Committee. An application titled "Macquarie University Human Research Application Form" was submitted to the Macquarie University Human Ethics Research Committee on 25th of September 2012 to investigate the technology usage of the farmers in Sri Lanka. This application was approved (Approval number: 5201200767). In September 2013, an application titled "Request for Amendment Form" was submitted to the Macquarie University Human Ethics Research Committee. The purpose of this submission was to amend the original application to gather additional information to improve the overall functionality, usefulness and usability of the mobile application. In March 2015, another amendment was made to the original application to deploy the mobile application and gather the responses of the farmers to measure the impact. All data will be kept secure for the mandatory period of 5 years using the approved methods and will be destroyed following that period.

3.11 Summary

This chapter discussed the research methodology (Design Science Research – DSR) that was employed in this research project. It provided an overview of the chosen research paradigm from which a detailed research plan was derived. The main research question was divided into sub-research questions. The three phases of DSR cycles were sub-divided and sub-research questions were aligned with them. This research approach was employed to solve the main research questions in the study systematically.

4 Towards an Empowerment Framework

A framework is a set of ideas or facts that provide support for something (Merram-Webster 2016). It is a real or conceptual structure intended to serve as a support or guide for the building of something that expands the structure into something useful (WhatIs.com 2016).

The main aim of this study was to: *develop and validate an empowerment framework that can be used to develop mobile-based applications which empower users in their livelihood activities.* In this chapter, the fieldwork investigations that address the first research question (RQ1) to find out the ideas, facts and/or a possible structure for an empowerment framework are discussed.

RQ1: *How can farmers be empowered in their livelihood activities*?

The main aim of research question 1 was to find out the elements of the empowerment framework by studying specific instances of farmer empowerment. To find the answers to this question, the investigation was needed to be carried out in several areas. First it was necessary to understand the goals of the farmers and the opportunities they have, and the obstacles they face in the agriculture environment. As this research focusses on empowerment, we then concentrated on understanding the concepts underpinning empowerment theory, psychological empowerment, the key drivers of empowerment and their relationships to each other. With the goals of the farmers, the concepts of empowerment theory and the aim of this study in mind, we then developed a definition of empowerment in the context of the Sri Lankan farmers. These concepts and ideas have helped us to create an *initial conceptual empowerment model* to represent the goals of farmers, associated empowerment processes and empowerment outcomes. In addition,

this study further investigated how technology can be used to empower the farmers and how farmers were making decisions prior to the introduction of the mobile artefact.

4.1 Goals of farmers and opportunities and obstacles in the Agriculture domain

In an organisation, when designing a replacement system or improving an existing system, users can specify functional requirements for a system because they have used such systems before and can identify the existing drawbacks, issues and inefficiencies. However, this was not the case for most of the farmers living in rural villages of Sri Lanka. They were not exposed to seeing or using such systems. Therefore, it was difficult for them to specify what the functional requirements of a system should be.

Good Design Science Research (DSR), as discussed in section 3.6, often begins by identifying and representing opportunities and problems in an actual application environment. The first step was to understand the problems, opportunities and the obstacles in the agriculture domain, and the hardships that farmers experienced. This process is related to the sub-cycle "*Relevance – understanding the problem (1)*" of DSR (see Table 4-1) below. We adopted a scenario-based approach for this purpose.

Scenario-based design is a set of techniques in which the use of a future system is described at an early point in the development process (Rosson and Carrol 2002). Narrative descriptions of envisioned usage episodes are then employed in a variety of ways to guide the development of the system to enable a user's experiences. Scenario-based design has a user-focused approach by looking at how users will use a system to accomplish their work tasks from which functional specifications can be derived.

Table 4-1: DSR sub-cycles of RQ1 (Copy of Table 3-3)

Research Question 1 (RQ1)	Method/technique used in DSR sub-cycle
RQ1: How can farmers be empowered in their livelihood activities?	
RQ 1.1 What are the goals of farmers and the opportunities and obstacles they have to achieve these goals?	Relevance -understanding the problem (1) Scenario-based approach
RQ 1.2 What is a suitable working definition for empowerment in the context of Sri Lankan farmers?	Rigor – Learning (1) Related literature review
RQ 1.3 What is an initial conceptual empowerment model for Sri Lankan farmers?	Design – heuristic search (1) Exploration of possible designs and identifying a suitable one
RQ 1.4 How can technology be used to empower farmers: stage 1 – Initial investigation?	Rigor – Learning (2) Causal analysis
	Design – heuristic search (2) Exploration of possible designs and identifying a suitable one
	Design – functional validation (1) Testing and correcting errors of the design
	Relevance – suitability validation (1) Questionnaire, Field trial
RQ 1.5 How can technology be used to empower farmers: Stage 2 – Enhancing profit calculator	Relevance – Understanding the problem (2) Related literature review
RQ 1.6 How do farmers make decisions?	Relevance -understanding the problem (3) Questionnaire, Field trial

The existing narrative descriptions were used to discover how farmers carry out their day-to-day tasks and the issues they face. Approximately 15 scenarios of Sri Lankan farmers in desperate and powerless situations reported in online newspapers were reviewed (Gunasekara 2012; Senaratne 2005; Sunil 2012; WSWS 2011). There were similarities amongst the issues and themes, and three different groups were identified. One representative narrative description was selected from each group. These scenarios

and the analysis of them are summarised in Appendix A. Analysis of these scenarios has helped us to understand current issues and farming practices. It has also given us an insight into what the farmers' personalised goals might be. With that knowledge, we have transformed the scenarios to identify the changes that need to happen for them to achieve their personal goals (see Appendix A). As most of the farmers have similar issues in their lives, a similar set of goals in all three scenarios were found.

4.2 Suitable definition of empowerment for the Sri Lankan farmers

This section discusses how a definition of empowerment in the context of the Sri Lankan farmers was decided. We draw on the empowerment theory and concepts presented in section 2.3 for this purpose. The study to define empowerment was related to the sub-cycle "*Rigor - Learning (1)*" of DSR (see Table 4-1) above.

Empowerment is a construct studied and shared by many disciplines such as community development, psychology, education, economics, health and many others. How empowerment is understood varies among these perspectives. As a result, there are many definitions for empowerment. (Rapport 1984) has noted that it is easy to define empowerment by its absence but difficult to define in action as it takes on different forms in different people and contexts. (Zimmerman 1984) has stated that asserting a single definition of empowerment may attempt to achieve a formulaic or prescription-like definition, and contradicts the very concept of empowerment. How we precisely define empowerment within our projects and programs will depend upon the specific people and context involved (Bailey 1992).

Empowerment is an abstract concept that is fundamentally positive, referring to solutions rather than problems. When empowerment is discussed, the concept of power is often mentioned. (Kuokkanen and Leino-Kilpi 2000). In the traditional social sciences, power is emphasized as influence and control, treating it as a commodity or structure

disconnected from human action (Lips 1991). The rural Sri Lankan farmers do not have the power or the knowledge to influence the government authorities or other organisations to address the issues that affect their livelihood activities. As a community, Sri Lankan farmers help each other when they face common problems and constant hardship. Therefore, the power the Sri Lankan farmers have is the social relationships that they have created in their culture. If these relationships are further enhanced with knowledge, efficacy and personal/community goal orientation, then the concept of empowerment becomes more meaningful (Cattaneo and Chapman 2010; Kanter 1979; Page and Czuba 1999).

Empowerment is a dynamic and an iterative process. It should have the room to define personal and meaningful goals, and evaluate and reflect on individual efforts towards achieving those goals (Cattaneo and Chapman 2010; Kieffer 1984). This iterative process for understanding the nature of goals, how they differ across people and contexts, evaluating and reflecting on people's efforts, can change the power of individuals. It can also change the power of relationships within groups and communities which in turn, impact on a society.

It can be reasonably argued that empowerment is, ultimately, a personal construct reflecting on the degree to which the values and attitudes associated with empowerment have been internalised. In other words, empowerment involves the acquisition of values and attitudes that are incorporated into an individual's personal worldview and thus constitute a foundation for action (Bolton and Brookings 1996). In the context of Sri Lankan farmers, the intrapersonal component of Psychological Empowerment discussed by Zimmerman would give them the power within to change individually, as a community and society (Zimmerman 2000).

After studying several definitions, we have chosen the following definition by (Cattaneo and Chapman 2010). It aligns with the context of Sri Lankan farmers and the aim of this study.

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

4.3 Initial conceptual empowerment model for the Sri Lankan farmers

After identifying the goals of the farmers, relating them to the concepts of empowerment theory and, defining empowerment in the context of the Sri Lankan farmers, the next step was to create an *initial conceptual model.* The function of the conceptual model was to represent farmer's goals, empowerment processes and tools to support empowerment activities and the outcomes. At this early investigation stage of my research, ideas were still evolving and we were starting to get a deeper understanding of empowerment and related concepts. The proposed empowerment model at that stage was considered to be preliminary with room for refinement.

The proposed conceptual empowerment model for farmers is shown in Figure 4-1 below. This design activity was related to the sub-cycle "*Design – Heuristic Search (1)*" of DSR (see Table 4-1) above. Analysis of the scenarios (See Appendix A) have helped us identify possible life goals of farmers: *have a secure job, have financial security, access to information for informed decision making, perceive alternative solutions, learn new skills, access education, feel safe, create a disaster recovery plan, and become an active community member.*

The possible empowerment processes that may assist them to achieve these goals: *planning farming processes, managing resources, calculating expenses and learning new skills* were identified next. These processes will be discussed further when the tools to support them are described in section 4.3.1.

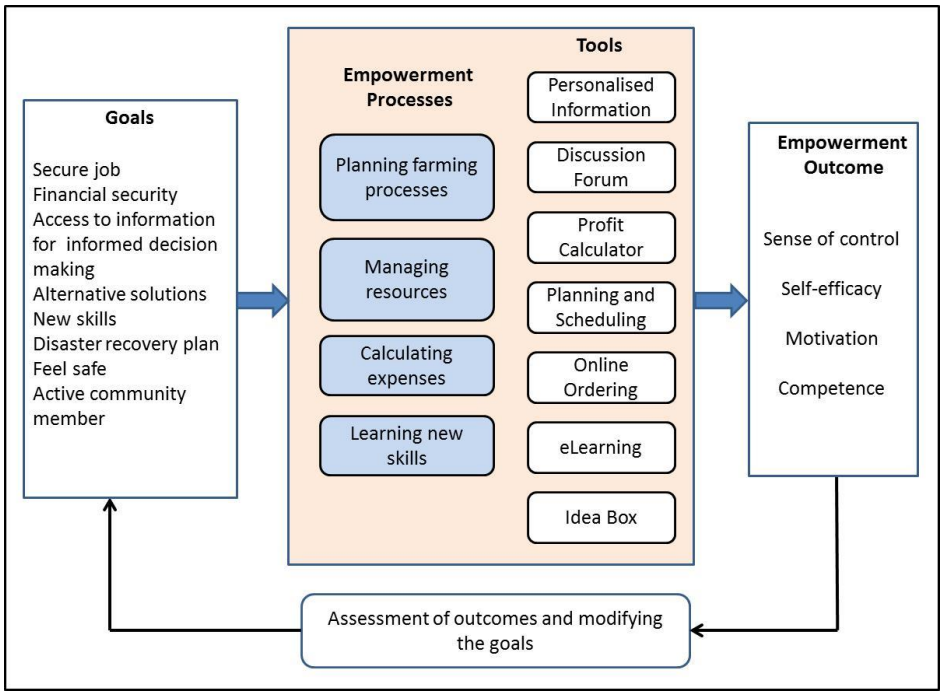

Figure 4-1 : Initial Empowerment model for the Sri Lankan farmers

When designing empowerment processes it is necessary to identify *empowerment outcomes* and how to *measure* them. Through applying empowerment theory and previous studies to our scenarios we identified four empowerment outcomes: *competence*, *sense of control*, *self-efficacy* and *motivation*.

A study by Bandura (1997) suggests that an individual's *self-efficacy* beliefs influence the choices made and the actions pursued. An individual should be able to see the resources that would assist them and the path to access these resources (Cattaneo and Chapman 2010). Access to personalised information and learning tools will increase their knowledge and competency and allow them a greater sense of control and self-efficacy.

4.3.1 Tools to support empowerment

To achieve empowerment outcomes, scenario transformations were used to identify tools that support empowerment activities. These tools are discussed below.

Personalised Information may help a farmer to choose what they would like to do, depending on their preferences. For example, depending on where their farm is located, rather than choosing the same crop to grow all the time, a farmer may want to grow something else. A farmer may make this decision because of a bad outcome from the previous season. Being able to make these decisions helps them to increase their self-efficacy belief that they can achieve their goals by their own efforts in their own environment.

A *Discussion Forum* tool may help a farmer discuss their issues with other farmers and exchange ideas and become aware of new ideas and alternative solutions. In general, Sri Lankans farmers help each other in their farming activities. Discussion forums should further help them become an active member of their community.

A *Profit calculator* may help a farmer to understand total expenses in their farming activities and expected income and profit. With this knowledge of expected profit, they will be able to make informed decisions about what actions which help them minimise or avoid future financial disasters. If a farmer does not know how to calculate expenses and expected income, they can use e-learning to learn this skill prior to using the profit calculator.

Planning and scheduling is a tool which may assist farmers create, plan and organise their own personal and community activities. Farmers often help each other when preparing their farm before cultivation start. Not every farmer owns farming equipment and so they hire them from other farmers. Farmers can use this tool to plan and schedule this type of farming activities.

An *online ordering* tool may help farmers with activities that are related to business transactions and banking processes. Along with the *Profit calculator, planning and scheduling* tools, *online ordering* tool will improve the farmer's business skills and support the empowerment outcomes of sense of control and self-efficacy.

eLearning may provide new skills and techniques to facilitate empowerment outcomes of increased knowledge and competence. *e-learning* is defined as instructional content or learning experiences delivered or enabled by electronic technology (Gallaher 2002). A study done by (Sharma et al. 2007) indicates that e-learners with higher intrinsic goal orientation and self-efficacy are likely to have better e-learning course performances. Depending on the goal of the farmers they can choose learning modules that provide them with new skills and allow them to set even higher self-efficacy goals.

An *Idea box* is a tool that may help farmers contribute their ideas and increase their self-efficacy. For example, a farmer may grow a new crop successfully or find out an inexpensive and efficient method to control a common disease. Farmers can share their new knowledge with other farmers via an *idea box.*

4.4 How technology can be used to empower farmers:

In this section, the preliminary investigations into how technology that can be used to empower farmers is discussed.

4.4.1 Exploring possible technology solutions for farmers

The study conducted to explore possible technology solutions for the farmers is related to the sub-cycle "*Rigor - Learning (2)*" of DSR (see Table 4-2) below. One of the empowerment goals for farmers was financial security (See section 4.3). The causal analysis carried out by the Sri Lankan research team identified that farmers make

important decisions at the key phases of a crop cycle such as crop choosing, growing and selling with the revenue in mind (De Silva et al. 2012). Therefore, it was necessary to find out how they make important decisions and how technology might assist them in the decision-making process. A simple profit-calculator on a smart phone was chosen to facilitate their decision-making process.

In recent ICT application development to support farmers in developing countries, calculators have been included as part of the application. For example, *Farmbook* is a basic business planning tool and profitability calculator that enables farmer registration to the application, builds business plans and evaluates the profitability of specific products in business plans of the farmers (Ferris 2011). The details of the *Farmbook* application were not available for study therefore it was not possible to comment whether it was a suitable application for farmers in Sri Lanka.

For the farmers in developed countries, a profit calculator might be seen as a very basic and simple tool. This is not the case for Sri Lankan farmers. Most of Sri Lankan farmers use basic mobile phones, not smart phones. They have not seen or used a tool like a profit calculator for decision-making. There are two supporting factors for us to consider. The first is the rapid growth of mobile phone usage in Sri Lanka: currently 98.04% of the total population in the country are mobile phone subscribers suggesting that the mobile phone has become a major part of people's daily lives (ITU 2015). The second factor is the revenue driven motivation and perseverance of farmers to carry on farming despite the constant hardships they face. It was decided to implement a profit calculator as a mobile-web application. It was specially implemented to calculate farming expenses, expected income and profit/loss.

Table 4-2: DSR sub-cycles of RQ1 (Copy of Table 3-3)

Research Question 1 (RQ1)	Method/technique used in DSR sub-cycle
RQ1: How can farmers be empowered in their livelihood activities?	
RQ 1.1 What are the goals of farmers and the opportunities and obstacles they have to achieve these goals?	Relevance -understanding the problem (1) Scenario-based approach
RQ 1.2 What is a suitable working definition for empowerment in the context of Sri Lankan farmers?	Rigor – Learning (1) Related literature review
RQ 1.3 What is an initial conceptual empowerment model for Sri Lankan farmers?	Design – heuristic search (1) Exploration of possible designs and identifying a suitable one
RQ 1.4 How can technology be used to empower farmers: stage 1 – Initial investigation?	Rigor – Learning (2) Causal analysis
	Design – heuristic search (2) Exploration of possible designs and identifying a suitable one
	Design – functional validation (1) Testing and correcting errors of the design
	Relevance – suitability validation (1) Questionnaire, Field trial
RQ 1.5 How can technology be used to empower farmers: Stage 2 – Enhancing profit calculator	Relevance – Understanding the problem (2) Related literature review
RQ 1.6 How do farmers make decisions?	Relevance -understanding the problem (3) Questionnaire, Field trial

4.4.2 Design of the Profit Calculator

One of the aims of this phase was to learn how farmers might use technology and how technology might assist them to make decisions at crucial stages of the crop cycle. To investigate this, a profit calculator for a smart phone was implemented. This design activity was related to the sub-cycle "*Design – Heuristic Search (2)*" of DSR (see Table 4-2) above.

The main functionality of the profit calculator was to calculate the profit or loss by using data provided by farmers. There are several stages in a crop cycle and for each stage there is a different set of expenses (De Silva and Ratnadiwakara 2010). Therefore, we have used a systematic and simple design approach for farmers to enter necessary data. The fertilizer cost, pesticide cost, labour cost and machine hire cost were identified as main expenses for the design based on a recommended crop growing procedure (Agriculture 2006). At different stages of a crop cycle, a farmer may apply different types of fertilizer and pesticide for their crops and need to hire people or machines to support various activities (Agriculture 2006; Lokanathan and Kapugama 2012). The design allowed a farmer to choose an expense category, choose an expense item in that category and enter necessary information to compute expenses (Figure 4-2). This expense data is then used to update total expenses for the fertiliser category and total expenses for the whole crop cycle. To calculate expected income, the farmer entered data for expected harvest and unit selling price. With values for total expenses and expected income, the profit calculator computed and displayed the profit or the loss Figure 4-2.

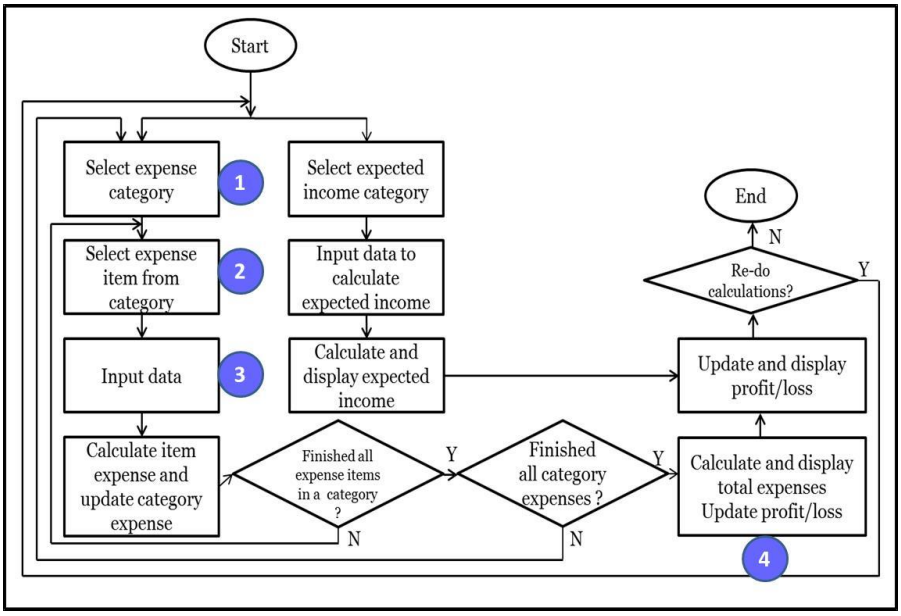

Figure 4-2 : Design of the Profit Calculator

The main screen of the profit calculator is shown in Figure 4-3 (Point 1 in Figure 4-2). It has three main functions: *total expenses*, *total income* and *loss/profit*. When the "Total Expenses" button on the main screen is clicked, a screen with a list of expenses such as fertiliser, pesticide, machine hire and labour hire is displayed (Figure 4-4, point 2 in Figure 4-2). When clicked on "Total Fertiliser Cost" button, it brings up the screen shown in Figure 4-5 (Point 3 in Figure 4-2). This allows the farmer to select a type of fertiliser from a menu, add the quantity of fertiliser required and the cost of fertiliser per unit. Clicking the "Save" button invokes the relevant expense calculation.

Figure 4-6 shows how the application displays various calculated costs (Point 4 in Figure 4-2). Farmers use their native language – Sinhala – when using the application. Figure 4-7 shows the screen that displays the calculated costs in Sinhala language.

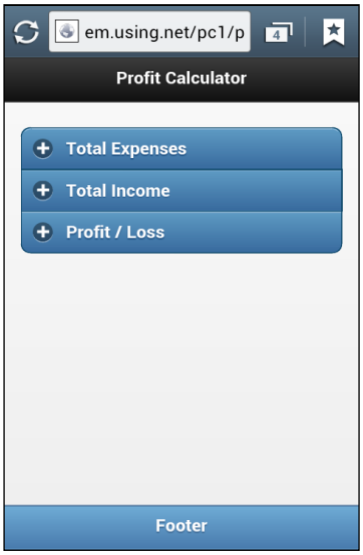

Figure 4-3 : Main Screen

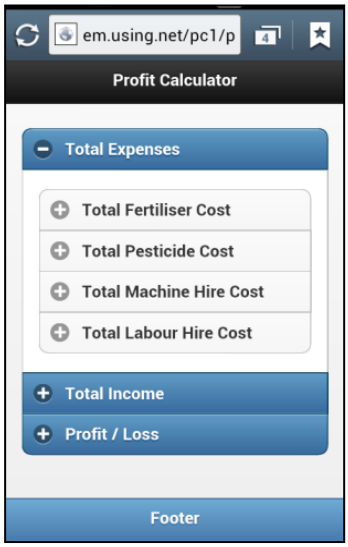

Figure 4-4 : Total Expenses Screen

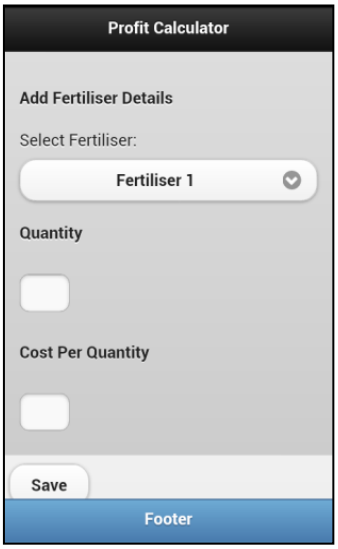

Figure 4-5 : Screen to add the details of fertiliser

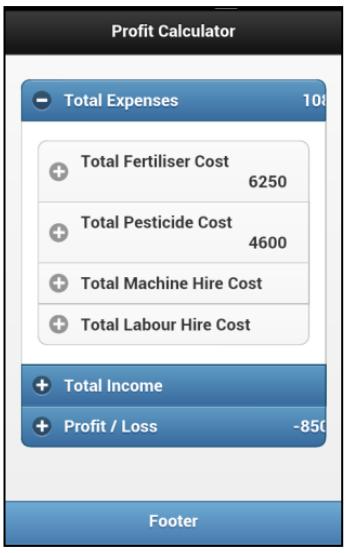

Figure 4-6 : Total expenses screen with calculated costs

Figure 4-7 : Total expense screen with calculated costs in Sinhala language

4.4.3 Field trial December 2012 - Field testing of the profit calculator

The next stage in the investigation was to field test the profit calculator with farmers. Prior to that, the research team validated functionality of the profit calculator. This activity was related to the sub-cycle "*Design – Functional Validation (1)*" of DSR (See section 3.9). Field testing of the profit calculator was related to the sub-cycle "*Relevance – Suitability Validation (1)*" of DSR (see Table 4-2 above).

Field testing of the profit calculator consisted of the following stages.

- Preparing for the field test
- Performing the field test
- Analysing the findings
    - Demographics
    - Initial farmer reaction to the profit calculator
    - Identifying further requirements
- Discussion

4.4.3.1 Preparing for the field test

The goals that were identified in scenario-based analysis were used to design and implement a prototype of the profit calculator (see section 4.3). The next step was to introduce and field test the prototype of the profit calculator in the environment in which it will be used.

In preparation for the field test, two questionnaires were designed to capture field test data (see Appendix B). The first questionnaire had closed-ended questions with multiple answers to capture demographic information, including gender, educational level, employment details, ownership of land, community involvement, decision making process, methods of accessing information, and mobile phone and internet usage. Capturing this information was important to create a profile of a farmer. The second questionnaire had both closed-ended questions with multiple responses as answers as well as open-ended questions. The objectives in using the second questionnaire were:

- to find out if, and if so, how farmers carry out a cost-benefit analysis at the beginning of a crop cycle
- to capture the reactions of the farmers of using the profit calculator

- to understand whether a tool similar to a profit calculator can successfully be used in the farming environment
- to understand the issues farmers may have experienced using a profit calculator
- to know whether a profit calculator would help farmers to make important decisions and improve their knowledge and skills.

In December 2012, the Australian researchers travelled to Sri Lanka for the first field trial. We selected two locations in Sri Lanka to field test our Profit Calculator: Dambulla and Galewela over two days. Dambulla is situated in the central province of Sri Lanka, 148km north-west of Colombo, the capital of Sri Lanka. Dambulla has the largest wholesale vegetable market in Sri Lanka. Galewela is another rural farming village 20 Km away from Dambulla (Figure 4-8) below.

Altogether there were 32 farmers involved in our study: 18 at Dambulla and 14 at Galewela. Each district in Sri Lanka has a dedicated agriculture officer who looks after the needs of the farmers. The research group at the University of Colombo, Sri Lanka organized farmers to attend this study via the agricultural officers at Dambulla and Galewela. The farmers were met at the agricultural offices at these two places. Five researchers from the Australian and Sri Lankan research groups were involved in this study which was conducted in the farmers' native language: Sinhala.

Figure 4-8 : Map of Sri Lanka

4.4.3.2 Performing the field test

Each farmer took approximately 1 hour to complete the first questionnaire (see Appendix B-Part A). The profit calculator application was made available to the farmers using the five smart phones. Farmers used the Sinhala (native language) version of the profit calculator. Each farmer was assisted by a member of the research team to understand the functionality and how to navigate through the various screens of the application. During this phase, the researcher asked farmers questions about their experience (see Appendix B-Part B). Smart phones were a novelty for the farmers hence it took each farmer approximately one hour to complete this part of the study. The last part of the field study used a questionnaire that consisted of both closed with multiple responses and open-ended questions (Appendix B-Part C). Each farmer spent approximately half an hour to complete the second questionnaire. In total, the study took approximately 2.5 hours for each farmer.

4.4.3.3 Results and analysis

The following section presents the results and analysis of the results.

- Farmer demographics
- Initial farmer reaction to the profit calculator
- Further requirements of farmers

Farmer Demographics

Table 4-3 presents the general demographics of the farmers. All the farmers who were present for this study were male with the majority (69%) having education to Year 10 only. Most (75%) owned their own farms and just over half (53%) were fully self-employed. Other 22% were doing different jobs in addition to the farming.

Table 4-3: Demographics of the farmers (Nov 2012)

Gender	Male	100%
	Female	0
Education	Up to year 10	69%
	Up to year 12	16%
	University graduates	9%
	No formal education	6%
Ownership of the farm	Owned	75%
	On lease	16%
	No comment	9%
Employment	Self-employed	53%
	Permanent contract	44%
	No comment	3%

At the time of this study, nearly 84% of the farmers had borrowed money to support their farming expenses at various stages of their farming career and 38% were in debt.

Regarding technology usage by the farmers, 84% had at least one mobile phone and of these, 7% had smart phones. Around 16% of the farmers, all of them were over age of 40, did not have a mobile phone. About 25% of the farmers had two mobile phones or more.

Nearly 94% of farmers' households had at least one mobile phone and 69% of the households had two mobile phones or more.

It was observed that 84% of the farmers did not use the Internet using a computer because they did not have a computer at home. The main reason was the high purchase cost, inability to use technology related to operating a computer and ongoing maintenance cost. About the activities the farmers carried out on the mobile phone; 80% used it to receive and make calls and nearly 30% used it to play games, send SMS, take photos, listen to radio and music files. About their awareness of possible Internet activities, 10% of the farmers used their mobile phones to browse the Internet, access Facebook and check bills, 30% were aware of available livelihood related Internet services.

Initial farmer reaction to the profit calculator

When field testing the profit calculator, we first demonstrated the functionality and navigation of the application to the farmers. They needed to enter data for four categories of expense*: fertilizer, pesticide, labour and machine hire*. Each expense category had a drop-down menu with four expense items to choose from. For fertiliser and pesticide expense calculations, once the expense item was selected, farmers had to input the quantity required and the unit price. For labour and machine hire expenses, farmers had to enter the hiring cost of a machine or a person per day and number of days that a service was required. Farmers also needed to enter data to calculate expected income. Using this data, profit calculator computed total expenses and displayed the profit/loss.

Though farmers took a while to get used to using a smart phone, at the end of the session, 97% of them reported that they understood the functions of the profit calculator, 81% found it easy to navigate through various screens, 91% agreed that it was easy to understand the instructions and 88% agreed that it was easy to carry out a profit/loss

analysis using an application on a mobile phone. Table 4-4 below shows the responses of the farmers to the profit calculator.

Table 4-4 : Farmer response to the profit calculator

Do you carry out cost-benefit analysis at the beginning of a crop cycle?	Yes - Logbook	42%
	Yes - Calculator	4%
	Yes – Logbook and calculator	19%
	Yes – In my mind	23%
	No	12%
Is there a difference between predicted income and actual income?	Yes	72%
	Sometimes	25%
	No	3%
Do you feel it would be beneficial to carry out a cost-benefit analysis	Yes	88%
	No response	12%
Do you understand the functions of the profit calculator?	Yes	97%
	No response	3%
Was it easy to navigate through various screens?	Yes	81%
	No	13%
	No response	6%
Was it easy to understand the navigational instructions?	Yes	91%
	No	3%
	No response	6%

Identifying further farmer requirements

In the second questionnaire, open-ended questions were used to further understand the expenses that are incurred in a farming cycle and what useful features farmers may like in an application like a profit calculator. To analyse the responses of these open-ended questions, we used a quantitative/quasi-statistical method (Saldana 2009). In this method of qualitative data analysis, data is first interpreted by coding to create an impression in a structured and quantitative form. As the responses were in the native language, the results were translated into English for analysis. The responses captured in the native language were read and each text segment that was meaningful to the domain of analysis was labelled with a code, usually a word or a short phrase in English. Farmers

were found to have used few different terms in their native language to describe the same concept.

During translation, one English word or short phrase was used in place of these different native language terms and coded in combination with the translation. For example, farmers used the words “wathura” and “jalaya” in Sinhala language to represent the word “water”. When coding was completed, similar codes were grouped together to create possible structured impressions to determine whether there were common themes or relationships among data.

The NVivo Software: Computer Assisted Qualitative Data Analysis package was used to generate tag clouds and to visually observe commonly occurring themes in the qualitative feedback provided by farmers. The word frequencies of these themes were calculated to quantify their importance from a farmer perspective. The coding approach and results were validated by a member in the research team after coding of the first 8 (25%). Validation involved review of the codes, and assignment of the codes to the transcripts in English. Disagreements were discussed and reconciled, leading to occasional changes to the original coding. Further validation was performed after 40%, 70% and 100% had been completed.

Figure 4-9, below, shows responses of farmers as to why it was difficult to predict their profit at the beginning of a farming cycle. Table 4-5, also below, shows the requirements proposed by the farmers.

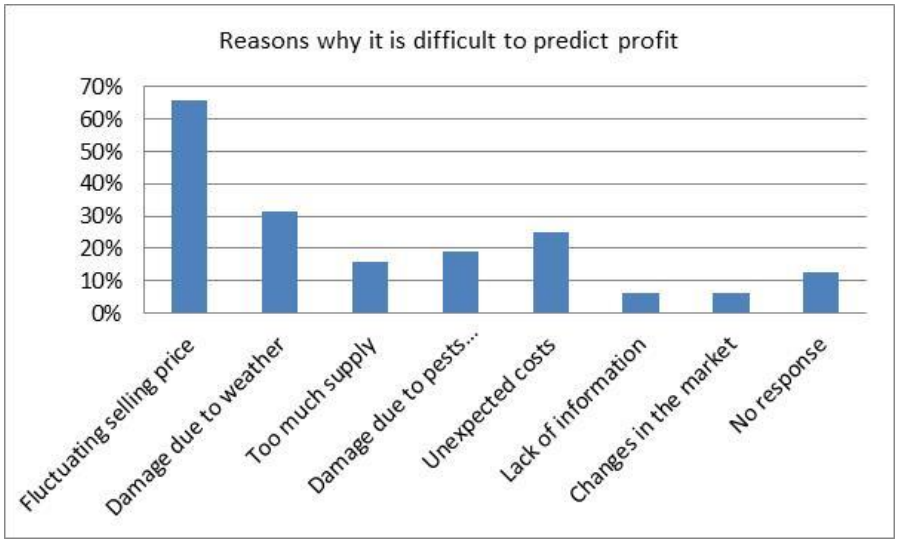

Figure 4-9 : Farmers' reasons why it is difficult to predict profit

Table 4-5 : Requirements proposed by farmers for the profit calculator

1	Ability to calculate expenses for the whole crop cycle and each stage
2	Ability to store and view the finalised expenses for later comparison purposes
3	Displaying profit as a percentage of expenses
4	Space for the farmers to add new expenses which are not listed in the application
5	Ability to provide location and size of a farm
6	Details of fertiliser and pesticide requirements specific to a farm
7	Correct units for fertiliser and pesticide to suit different forms (liquid, powder and granular)
8	Reliable, complete, up-to-date and accurate information
9	Space for the farmers to enter new information and ideas
10	Information about areas where there is a high demand for a particular product

4.4.4.4 Discussion

One of the objectives of the field test was to discover if, and how, farmers carry out a cost-benefit analysis at the beginning of a crop cycle. The responses in Table 4-4 show that only 19% of the surveyed farmers used a systematic approach to calculate and record their expenses. Furthermore, only 42% of them recorded how much money they spent in a logbook but did not use a calculator to compute expenses before making purchases. Therefore, at the shops, they did not have knowledge to compare whether they were spending too much money. It was observed that 4% of the surveyed farmers used a

calculator to compute necessary expenses but did not keep a record. As a result, they did not know the total amount of money they had been spending. 23% of farmers did a mental calculation and 12% of them did no analysis.

Whether or not farmers did cost-benefit analyse and kept records of their expenses at the beginning of a crop cycle, all farmers had an approximate idea of what their net revenue might be, however, they were reluctant to discuss it. It is a cultural belief that they should not talk about good outcomes that are yet to happen in the future. 72% of the surveyed farmers reported a difference between their predicted income and actual income. This included all the farmers who did the computations using a calculator and kept records on logbooks.

It was observed that 25% of the farmers reported that their predicted and actual income was different only sometimes and 3% of them said there was no difference. The reasons they gave for this difference were: fluctuating selling prices in the market (66%), damage to crops due to the unpredictable weather conditions (31%), damage to the crops due to pests and diseases (19%), too much supply in the market (16%) and unexpected costs (25%). Nearly 67% of the farmers who did not carry out a cost-benefit analysis reported unexpected expenses as one of the reasons for this difference (See Figure 4-9 above). Around 88% of the farmers agreed that it is beneficial to carry out some cost-benefit analysis on their expenses during a crop cycle.

These observations indicate that the surveyed farmers did not use systematic and useful methods to calculate and analyse their farming expenses. In the scenario analysis, we carried out (See section 4.1 above), we identified that financial security was one of the farmers' important goals. Because of not using proper processes to keep track of their finances, and with the added reasons as shown in Figure 4-9 above, it was difficult for farmers to achieve financial security.

Though farmers took some time to become familiar themselves with the profit calculator application on a smart phone, they could understand the functions (97%), navigate through the screens with ease (81%) and understand the navigational instructions (91%). This gave them the confidence to describe the additional functionality that they would like to see in the design of a future application (Table 4-5 above). Farmers mentioned that having a better understanding of their expenses in the various stages of the crop cycle and an awareness of different suppliers may help them to better manage their expenses. On average, each farmer listed at least four expense items that influence their total expenses.

In addition, they proposed the following additional requirements:

- history of expense details for future comparisons and analysis
- display profit as a percentage
- space for farmers to enter new expenses and information
- correct units of fertiliser and pesticide as they come in different forms such as powder liquid and granular form
- space for a farmer to enter the location and size of a farm and then receiving the information that is specific to that farm
- facility to obtain loans via banks during financial hardships.

4.4.4 Objectives achieved and insights gained after December 2012 field trial

In the field trial, we achieved the following four objectives:

a) To meet Sri Lankan farmers for the first time.
b) To understand how farmers use technology and discover related issues.
c) To understand whether our prototype can be used in a farming environment successfully.
d) To understand and provide an opportunity for farmers to specify their own requirements.

Furthermore, from the December 2012 following insights were gained.

a) Farmers need customised information that helps them to achieve their personalised goals.
b) Farmers make important decisions at the important stages of the crop cycle. At these stages, farmers need access to relevant information to make informed decisions.
c) Farmers need factual (just the facts) as well as procedural knowledge (how to apply the factual knowledge) that helps them use factual knowledge meaningfully.
d) Factual knowledge and procedural knowledge should be provided via different tools to support empowerment activities.

4.5 Enhancing profit calculator to provide detailed expenses in farming stages

When the prototype of the profit calculator was first developed, its main function was to calculate total expenses for a whole crop cycle rather than for each stage. It was also evident from the 2012 field trial that farmers could benefit from a tool like a profit calculator. The field trial further revealed that a stand-alone profit calculator without any integration to the various parts of a farming process did not help farmers to plan and evaluate their finances when they were in the process of deciding which crop to grow. One of the insights that was gained from the 2012 field trial was the importance of having details of expenses for the whole crop cycle as well as for each stage. This was incorporated in the design by studying details of each crop cycle stage. This included the various activities, related expenses and information requirements of each stage. This process is related to the sub-cycle "*Relevance – understanding the problem (2)*" of DSR (see Table 4-2 above).

4.5.1 Stages of a crop cycle

There are six stages in a crop cycle. The activities that are carried out and the information needs of each stage are different (Lokanathan and Kapugama 2012).

- *Deciding stage*: This is the stage when farmers decide on which crop to grow, how much land to allocate for each crop and how to arrange financing. In this stage the majority of farmers make their decisions by themselves (Lokanathan and Kapugama 2012). It can be based on higher yield crops, market demand and sale potential of the crops, prices of the crops in the previous and current seasons, and budget required for the cultivation and crop diseases.
- *Seeding stage*: During this stage farmers either purchase seeds or prepare their own seeds. When selecting seeds, farmers consider the cost and quantity needed per acre of land, suitability of seeds to a particular area and climate, water requirements and resistance to diseases. They might prepare a seed bed during this stage.
- *Preparing and planting stage*: Land preparation using labour or machines, and actual planting occur during this stage. Farmers may hire machines and/or labour and organise water to their farms. If there had been any impact due to disease from the previous cultivation, farmers use fertiliser to the soil to bring the land to its normal fertility.
- *Growing stage*: Applying fertilizer, pesticides and water occur during this stage. Unexpected diseases and new pest problems can occur during the growing stage. Farmers keep a close watch for these common issues and seek help to solve problems from agriculture officers, friends and the shops that sell chemicals.

- *Harvesting, packing and storing stage*: Finding labour for harvesting, packing, and storing are the main activities that happen during this stage. Finding labour has become difficult in recent years and not finding it on time may delay harvesting. Sometimes unexpected weather during this period may affect the quality of the harvest or destroy the harvest altogether.

  Farmers may have to hire machines to harvest if they do not already have them. In a case of paddy, they need to maintain a certain level of dryness to get a good price in the market. Some farmers find a larger area to spread the paddy to dry but it is a challenge to find suitably large areas. Some farmers use drying facilities in the mills.

  In the case of paddy farming and some vegetables such as onion, farmers may not sell their harvest soon after the harvesting. They may store them until there is a good price in the market. Farmers often store them in their houses though sometimes it may be affected by rats and other insects.

- *Selling stage*: In the final stage, some farmers check selling prices at the market. They use correct packing material to pack their harvest appropriately to minimise damage during transport, find a suitable method of transportation, transport the packed harvest to the market and sell.

4.5.2 Expenses related to each stage of a crop cycle

As explained in section 4.5.1, each stage of a crop cycle has multiple activities and an expense is incurred when carrying out each activity. To compute the expense of each stage, all the activities of each stage were listed. Table 4-6 below shows all the activities that we used in our implementation. Activities in the deciding stage of a crop cycle mainly involved searching and the relevant cost for this stage could not be easily quantified. This cost therefore was not included in the implementation. The main activity in the seeding

stage is organising seeds, therefore it was included in the preparing and planting stage for easy implementation. The cost associated with these activities was used to calculate the expenses of each stage and the whole crop cycle.

Table 4-6 : Activities of each stage of a crop cycle

Activity	Preparing and planting stage	Growing stage	Harvesting, packing and storing stage	Selling stage
Labour cost calculation	x	x	x	x
Chemical cost calculation	x	x		
Fertiliser cost calculation	x	x		
Machine hire cost calculation	x		x	
Packaging cost calculation				x
Pesticide cost calculation	x	x		
Seed cost calculation	x			
Transport cost calculation			x	x
Water cost calculation	x	x		
Applying for micro-finance	x	x	x	x
Online ordering	x	x		
Discussion forum	x	x	x	x

4.6 How did farmers make decisions – prior to the introduction of the mobile artefact

In addition to identifying new user requirements, the systematic analysis during the 2012 field trial data led to the discovery of deeper needs of farmers and this assisted to develop a basis for developing a framework to empower farmers. To understand decision making in farming processes, the following questions related to the sub-cycle "*Relevance – understanding the problem (3)*" of DSR (see Table 4-2) were investigated.

- what information do farmers need to carry out activities in the farming processes?
- how do farmers receive the required information?
- how do farmers use this information?
- what choices do farmers have when making decisions?
- how farmers engage and communicate with each other?

- how do farmers interact in society and what obstacles do they face during the farming cycle?

It was also considered that more information was needed on the self-efficacy or the self-belief of farmers about their capabilities and how this influences the events that affect their lives. (Bandura 1997). Self-efficacy is one of the core elements of the empowerment process and determines how people feel, think, motivate themselves and behave. Therefore, to further understand the requirements, needs, issues and how the farmers carry out farming processes and make decisions, we conducted our second field trial in November 2013.

4.6.1 Field trial November 2013

In November 2013, an extensive field trial was carried out to understand the activities that farmers carry out in farming, the information they need to carry out the farming processes, how they receive the information and how they use this information to make decisions. Farmers were interviewed and questionnaires were used to gather additional relevant information.

The field trial consisted of the following stages:

- Preparing for the interviews
- Conducting the interviews
- Results and analysis
    - Demographics
    - Agriculture Planning Self-efficacy levels of the farmers
    - Discussion

4.6.1.1 Preparing for the interviews

In preparation of the interviews, a questionnaire was designed (see Appendix C). The objective of the questionnaire was to collect general demographics of farmers, their technology usage, and the confidence levels of their capabilities in planning various activities in a farming cycle (See Appendix C-Agriculture Planning Self-efficacy questions). This questionnaire also had semi-structured, open-ended questions to guide the subsequent interviews. The aim of these open-ended questions was to understand how farmers behave when they take actions while doing their livelihood activities. Therefore, the questions were designed to find out which information is available for the farmers to make informed decisions and how they make them, how they find information and apply them in action, choices they have and autonomy to choose, their strengths and weaknesses, commitment, beliefs about their competency and their engagement in the community (see Appendix C).

The questionnaire consisted of the following four parts.

1. Part A – questions with closed-ended responses to collect demographic details of farmers
2. Part B – questions with closed-ended responses to collect information about the technology usage of the farmers
3. Part C – open-ended questions to guide the interviews – These were designed to guide the discussion in the areas of their market/IT/financial/cop knowledge, leadership skills and community activities
4. Part D – Agriculture Planning Self-efficacy questions

Design of an instrument to measure Agriculture Planning Self-efficacy

Perceived self-efficacy is defined as; people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives (Bandura 1994). People differ in the areas in which they cultivate efficacy. They differ therefore in the efficacy levels within a domain. The self-efficacy belief system is not a global trait but a different set of self-beliefs linked to distinct realms of functioning (Bandura 1997).

When developing an instrument to measure self-efficacy, we referred to Bandura's Guide for Constructing Self-Efficacy (Bandura 2006). There is no all-purpose measure of perceived self-efficacy. For measurement purposes, self- efficacy items must be created for a specific situation, should be valid and accurately reflect the construct. Self-efficacy scales must be tailored to activity domains and assess the multifaceted ways in which efficacy beliefs operate within the selected activity domain (Bandura 1997). For example, in the farming domain there are many functional areas and stakeholders, and a farmer is one of the stakeholders. A farmer is involved in many functional areas of the farming domain such as participating in farmer association meetings or leasing a land or carrying out farming activities during the farming season. To target the self-efficacy scales to the domain of functioning, the farming activities of all the stages of a farming cycle were chosen. Perceived self-efficacy should be measured against levels of task demands that represent gradations of challenges. Therefore, when the instrument was designed, routine farming activities that farmers normally do such as, deciding how to apply various fertiliser to a crop correctly, as well as challenging tasks such as whether to exercise influence to change a decision taken by government authorities were included.

An important aspect of the instrument is the response scale. In the standard methodology for measuring self-efficacy beliefs, individuals are presented with items portraying

different levels of task demands, and they rate the strength of their belief in their ability to execute the requisite activities. As shown in Figure 4-10 below, they record the strength of their efficacy beliefs on a 100-point scale, ranging in 10-unit intervals from 0 ("Cannot do"); through intermediate degrees of assurance, 50 ("Moderately certain can do"); to complete assurance, 100 ("Highly certain can do") (Bandura 1997).

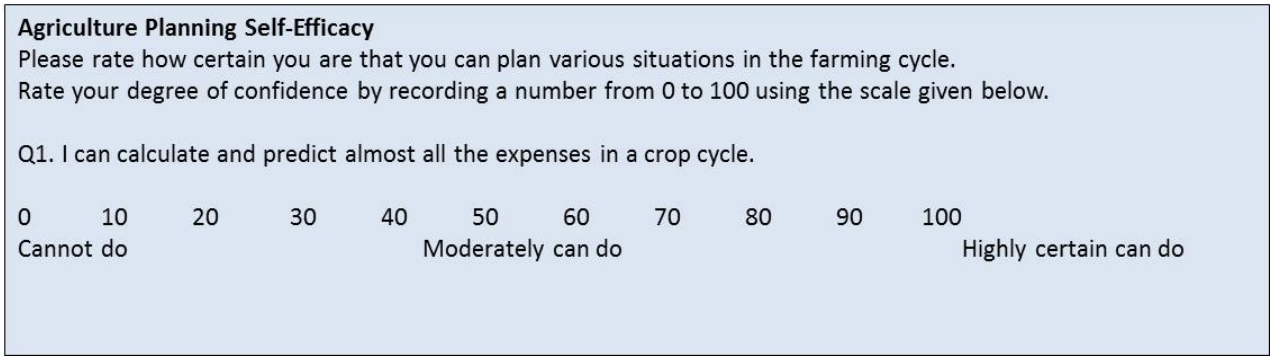

Figure 4-10: Sample Self-Efficacy question with scale

4.6.1.2 Conducting interviews

Interviews were conducted with 50 Sri Lankan farmers at six different locations over five days. The major cities closest to these locations were Dambulla, Pollonnaruwa and Galigamuwa. We spent 2 days at Dambulla with 19 farmers, 1 day at Galigamuwa with 10 farmers and 2 days at Pollonnaruwa with 21 farmers. The research group at the University of Colombo, Sri Lanka organised the farmers to attend the study via agricultural officers at Dambulla, Galigamuwa and Pollonnaruwa. Farmers were met at the agricultural offices at Dambulla and Pollonnaruwa and at a farm at Galigamuwa. Five researchers from the Australian and Sri Lankan research groups were involved in this study. It was conducted in the farmers' native language, Sinhala.

Each farmer took approximately 1 hour to complete parts A, B and D of the questionnaire (see Appendix C). The interviews conducted in Part C were approx. 20 minutes long and

recorded. The audio files of these interviews were transcribed to create text files in Sinhala. This was carried out by a research officer at Peradeniya University in Sri Lanka.

Each transcript was marked up by reading the transcript one-by-one and reviewing the interview response against the knowledge that is required in the farming domain. For example, the details were recorded on the different types of knowledge the farmers had such as crop knowledge, market knowledge, IT knowledge and financial knowledge. A count of the number of farmers who talked about this knowledge was recorded. Nvivo10 software was used to perform the content analysis coding described above. To maintain consistency in coding among the groups at different places, we first coded 10 transcripts in total (20%) from the three places (4 from Dambulla, 4 from Pollonnaruwa and 2 from Galigamuwa). The coding approach and results were validated by another member in the research team. Validation involved review of the codes, and assignment of the codes to the transcripts in English. Disagreements were discussed and reconciled, leading to occasional changes to the original coding. Further validation was performed after 40%, 70% and 100% had been completed.

4.6.1.3 Results and analysis

The following section presents results and analysis of the 2013 November field trial.

Farmer Demographics

Table 4-7 below shows the general demographics of the farmers interviewed. The majority were male (86%) and most (58%) having only up to Year 10 education. Most (80%) owned their own farms, 10% worked on farms on lease and another 10% did not want to discuss the ownership and other arrangement with the farms. The majority (76%) were self-employed and the rest (24%) worked on contract basis.

Table 4-7 : Demographics of the farmers (Nov 2013)

Gender	Male	86%
	Female	14%
Marital status	Married	90%
	Single	8%
	Widowed	2%
Education	Up to year 6	14%
	Up to year 10	58%
	Up to year 12	20%
	Diploma	4%
	University graduates	2%
	No formal education	2%
Ownership of the farm	Owned	80%
	On lease	10%
	No comment	10%
Employment	Self-employed	76%
	Permanent contract	24%

Regarding technology usage, 82% of the farmers had at least one mobile phone, 12% had two mobile phones and 6% had none. Most households (98%) had at least one mobile phone, 74% of the households had two mobile phones, 32% of the households had three mobile phones and 14% had four mobile phones. Most of the farmers (82%) did not use the Internet using a computer as they did not have one at home. The main reason for this was the high purchase cost, inability to use technology related to operating a computer and ongoing maintenance cost.

Discussion

During the interviews, farmers identified the knowledge that they thought was important for them. Figure 4-11 below shows the number of farmers who talked about the different types of crop knowledge they had. Most of the farmers described the damage that was done by pests (56%) and diseases (50%). They further discussed how important it was to have access to information and solutions to quickly control the damage done by the pests (44%) and diseases (44%). About 34% of the farmers talked about the importance of acquiring good seeds and being able to buy quality fertiliser to have a good harvest at the

end of a farming season. Other factors that farmers mentioned were weeds (2%), weed control (8%), difficulty in organising water (2%) and easy access to different chemical products throughout the farming season (6%).

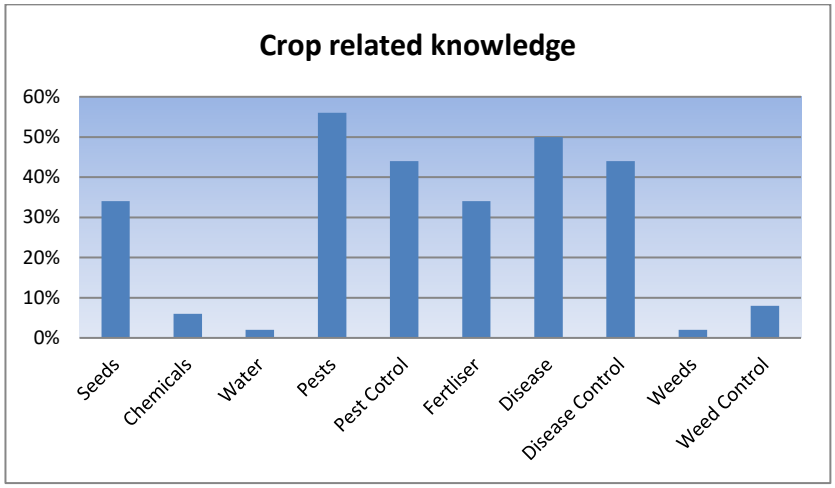

Figure 4-11 : Crop related knowledge

Farmers also discussed other types of knowledge that they have; which we have classified as related to the; market, IT or financial. About 48% of the farmers discussed the difficulty of predicting selling prices in an unstable market and the logistics related to organising transportation, storage and wastage (Figure 4-12) below. Most of the farmers lacked financial knowledge (4%) and IT knowledge (4%) hence did not discuss these types of knowledge much.

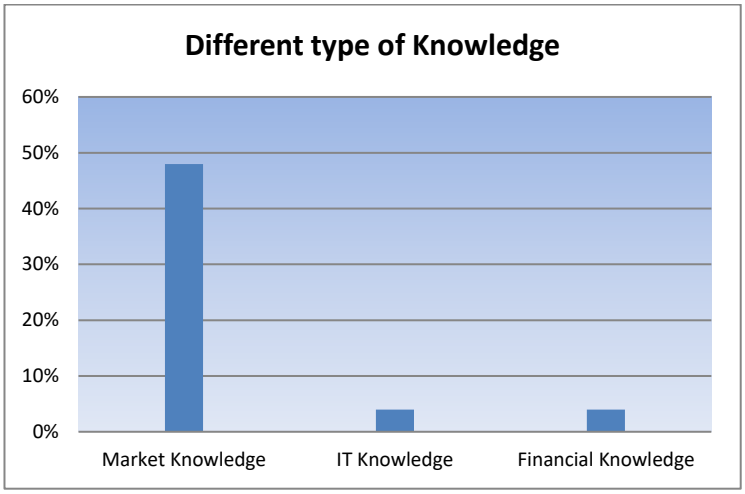

Figure 4-12 : Different type of knowledge

It was clear from the interviews that knowledge management was an issue for the farmers, as evident in the quotes from the interviews below.

One farmer said:

> *"I would like to have a better understanding of my expenses. Every season, things are becoming very expensive, such as fertilizer, pesticide, chemicals etc. I run into debts sometimes. I would like to know how to calculate these expenses properly" (a male farmer from Dambulla, Age: 31 - 40)*

This statement reveals the need for factual knowledge concerning costs and procedural knowledge on how to manage expenses. As further examples, the two quotes below reveal a lack of knowledge and access to knowledge.

> *"I am a new farmer. My problem is that I do not have much knowledge. I can get the information from the agriculture officers but if I can learn how to grow something new by myself, that would be good. I have access to the Internet and I like to read and learn new ideas" (a male farmer from Pollonnaruwa, Age: 31-40)*

"We are not knowledgeable about the crop diseases. We don't know what chemical to use. We need to depend on the shops that sell them. Most of the time we have to try more than one shop, resulting many trips to the shop. We have no choice. This is very expensive for us and in the end our crop gets damaged as we were late to provide a solution" (a female farmer from Dambulla, Age: 41-50)

The next quote demonstrates the uncertainty faced by farmers and the need to adapt, revise and update their knowledge in quick response to their environment.

"Last season our crops contracted a new disease. We could not recognize it and even the agriculture officers did not know what that was. By the time we found a solution, it was too late. Our whole crop got damaged. We need to identify them quickly and provide a solution quickly too" (a male farmer from Dambulla, Age: 41-50)

The next two quotes demonstrate the need and desire to share and reuse knowledge with others.

"We don't know what others are growing. Most of the time, we all grow the same thing because of the good selling price we received for a crop in the previous season. Then the market becomes saturated with that crop and the selling price goes down. I would like to know what others are growing and receive advice on what else I can grow and how I can grow it" (a male farmer from Dambulla, Age: >51)

"I make my own organic fertilizer and would like to sell it to our own community of farmers. I can't compete with big suppliers. It would be good for us to have an avenue via technology to advertise and sell our own products" (a male farmer from Pollonnaruwa, Age: 31 - 40)

Agriculture Planning Self-efficacy levels of the farmers

These results will be discussed in section 6.3.4.

4.7 Insights gained from the 2012 and 2013 field trials

The 2012 and 2013 field trials revealed how farmers find information to carry out the activities in a crop cycle. Farmers use the knowledge they have gained through years of experience to perform their farming activities and often use their intuition to make decisions. Farmers typically rely on agriculture officers; fellow farmers; family and friends; TV, radio and newspapers for information which may not be up-to-date, accurate or relevant. Often farmers should travel to offices of the Agricultural Department to find out information they need and this is a costly and time-consuming activity. Sometimes the availability of government officials is unpredictable. Radio or TV programs are broadcasted at a predefined schedule which may or may not be convenient for the farmer. The Agriculture Department has published farming related information as pdf documents on their website (Agriculture 2011) and booklets.

This information is general in nature, incomplete and unstructured. Many of the farmers do not use computers due to its high purchase and maintenance cost, and lack of their computer skills. The farmers who do not use computers were not aware of the information provided on the website. A farmer who has a low level of computer competency may be overwhelmed with the amount of information they receive via different sources in different formats and not feel empowered to search for information in a process that they view as complex. This lack of empowerment includes being unaware of alternative choices that are available and lacking the knowledge, self-confidence and competence to look for them. When there is lack of self-belief, a farmer may not be intrinsically motivated to achieve meaningful goals. This limits the amount of discovery, exploration or learning possible, in the decision-making process. Being able to set

personally meaningful goals, and reflecting on the impact of the actions taken is important to achieve these goals.

From this investigation, Figure 4-13 below was created which illustrates how farmers have been making decisions prior to the introduction of MBIS. The access that farmers have for useful information is limited. The information they find is often not up-to-date or relevant. As a result, farmers make uninformed decisions that can lead to limited success or failure at the end.

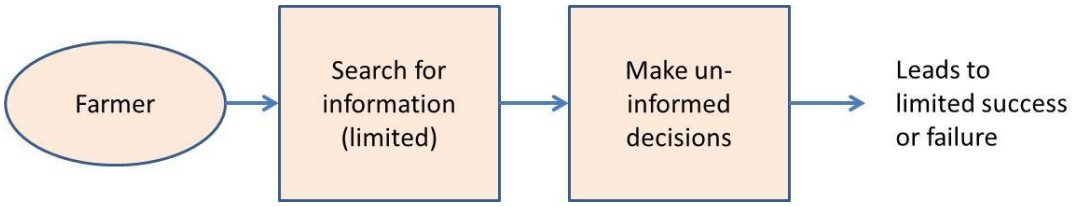

Figure 4-13 : Decision making in current farming processes

4.8 Characteristics of empowering farming processes

This section will discuss how the investigation helped in to design empowering processes in our application. Empowering processes might include opportunities to develop and practice skills, to learn about resource management, to work with others on a common goal and to expand social support network (Zimmerman 1995). Empowering processes may result in empowered outcomes such as sense of control, motivation, self-efficacy and competence, and have an effect on all three components of psychological empowerment (Kieffer 1984; Zimmerman 1988; Zimmerman et al. 1992).

Important insights were gained from the investigations into the requirements of an empowering processes and a method to fulfill these requirements. It was clear that farmers need easy access to actionable information. This information should be in an easy to understand and usable format.

There are different types of information that farmers need: factual and aggregated. For this information to be meaningful for a farmer, it should be customised. Therefore, when designing empowering processes in the application, it should have customised factual and aggregated information in a suitable format. The utilization of this information depends on the method that is used to provide it. The method is to organise the information to provide choices. These choices should be related to a task, easy to identify and evaluate, and lead to making informed decisions.

4.8.1 Relationship between choice and empowerment outcomes

The investigations revealed that farmers did not have much of a choice in their decision-making process. This section was included here (not in the literature review) as lack of choice in decision making was discovered during the investigations. This section will discuss the importance of having choice in empowerment.

Research has shown that the mere exercise of choice itself may have psychological benefits. When individuals are offered a choice, they may feel a sense of autonomy, control, or empowerment (Iyengar and Lepper 1999). Participating in decision making, goal setting and ownership in organisational outcomes are some ways that employees can be empowered. Providing employees with choice in how they approach to do tasks and solve problems is another powerful concept that can be used. Choice gives people a sense of personal control and agency, which in turns enhances their intrinsic motivation toward their work. The results include increased employee morale, higher creativity and innovation, better performance, greater organizational commitment, and lower turnover (Chua and Iyengar 2006). The following section discusses the relationship between choice and empowerment outcomes such as sense of control, motivation, self-efficacy and competence.

4.8.1.1 Sense of control and Choice

Sense of control is perceived control and refers to user's internal assessments of objectively established freedom whereas autonomy refers to a degree of discretion or freedom embedded in organisational structures or job characteristics (Halaby and Weakliem 1989; Hall 1986). In the Self-Determination Theory of Motivation (SDT), autonomy plays a central role as one of the basic needs. The need for autonomy refers to the need to feel a sense of full volition and choice-fullness regarding one's activities and goals, a feeling that emerges when one's actions and goals are experienced as emanating from one's authentic self (Deci and Ryan 1985; Ryan 1993). There has been a growing body of research to demonstrate that a high level of sense of control increases the performance and satisfaction in the activities that users perform (Deci and Ryan 1985; Greenberg 1975; McNeely 1983; Rotter 1966; Taylor and Brown 1988). Psychological studies that focussed exclusively on sense of control assert that control can have an effect only if it is perceived (Langer 1983; Miller 1980). They argue that merely believing that one has control, even if that control is never actually exercised, can be psychologically beneficial (Miller 1980; Parker 1993).

A construct that is related to sense of control is choice. Choice process theory assumes that sense of control is a consequence of exercising greater choices. The theory also stipulates that a set of feasible choices is partly dictated by given organisational structures and jobs, and partly shaped by employees' choice processes (Elster 1986; Lawler 1992). Any social structure can have both constraining and enabling effects on choice (Giddens 1984). Actors interpret a social structure primarily in terms of either the constraints it imposes or what it enables them to do. This interpretation can be characterised as the actor's sense of control and can cause external events by manipulating the environment (Kanter 1972; Westcott 1988). Choice processing involves reshaping, estimating,

developing, and interpreting a set of given choice opportunities. The choice process theory indicates that this active involvement in choice processes generates sense of control beyond the objectively established set of choices.

According to SDT, people feel autonomous when they feel and/or understand the value or relevance of the task in which they are engaged, and therefore can identify with it. Feelings of autonomy are particularly strong when the task is perceived as being closely connected to the values, interests, and goals that constitute the core of one's authentic self and identity (Assor et al. 2005; Reeve et al. 2003; Ryan 1993). Further (Deci and Ryan 1985) note that self-determined choices are those based on an awareness of one's organismic needs and a flexible interpretation of external events.

4.8.1.2 Motivation and Choice

SDT places a particularly heavy emphasis on the role the need for autonomy in promoting intrinsic motivation (Deci and Ryan 2000). SDT-based research has shown that autonomy-supportive contexts enhance both intrinsic motivation and well-being (Deci 1971; Deci and Ryan 2000; Deci et al. 1996). Across many domains of inquiry researchers have contended that providing choice will increase the feelings of intrinsic motivation (deCharms 1968; Deci and Ryan 1985). Conversely, the absence of choice and control has been hypothesised and shown to produce a variety of detrimental effects on intrinsic motivation, life satisfaction, and health status (Deci et al. 1982; Schulz and Hanusa 1978). When individuals are offered more choices with different preferences, they can find and select alternatives that best match their personal preferences.

4.8.1.3 Self-efficacy and Choice

Self-efficacy judgements or the individual's beliefs in his or her capacity to execute behaviours necessary to produce specific performance attainments influence choice of activities (Bandura 1982; Bandura and Schunk 1981). In his social cognitive theory, Bandura proposes that individuals' self-efficacy is the major determinant of goal-setting, choice of activity, willingness to expend effort, and persistence (Bandura 1977). People avoid activities that they believe exceed their coping capabilities, but they undertake and perform assuredly those that they judge themselves capable of managing (Bandura 1977). Thus, judgments of one's capabilities partly determine choice of activities and rate of skill acquisition, and performance mastery, in turn, can boost perceived self-efficacy in a mutually enhancing process.

4.8.1.4 Competence and Choice

One of the psychological needs recognised by SDT is the need for competence. The need for the competence is the need to be effective in one's interactions with the environment, and to feel that one is capable of mastering challenges (Deci and Ryan 1985; Deci and Ryan 2000). A rich body of research on the achievement motive (Weiner 1992) suggests that most people tend to choose tasks of intermediate difficulty, as this type of task gives them the most information about their capabilities and provides an optimal opportunity to increase their sense of competence (Deci and Ryan 1985; Pintrich 2003; Pintrich and Schunk 2002; Weiner 1992). These findings indicate that choices which offer options of intermediate difficulty are competence-supporting and therefore motivating. In contrast, choice options that are too easy or too difficult undermine motivation.

These notions from the literature have been combined below in Figure 4-14 to show the relationships between the choice and intrapersonal component of PE.

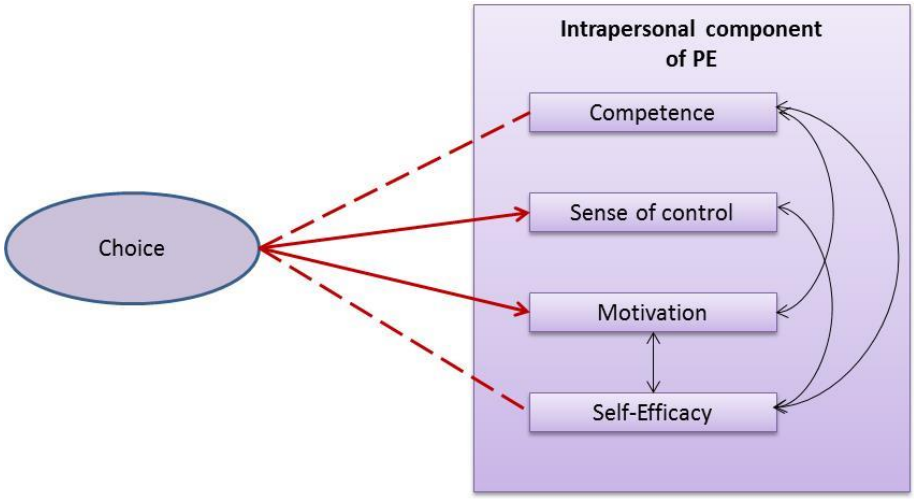

Figure 4-14 : Relationship between choice and empowerment outcomes

Therefore, *choice* was embedded in designing the empowering processes of the MBIS application for farmers to identify and engage in choice processes, learn and develop new skills, reshape the set of given choices to be personally feasible within their specific situations, and evaluate all possible choices available and make decisions.

4.9 Summary

This chapter has presented the details of the investigation that helped in to determining the elements of an empowerment framework for farmers in Sri Lanka. To find these elements of an empowerment framework, two field trials were conducted with Sri Lankan farmers. During these field trials, it was observed what information farmers need, the nature of the information with regards to its currency, completeness and relevancy, and how farmers find the information. This revealed how un-informed decision making sometimes leads to unsuccessful outcomes. Information was also gathered on the additional expense requirements farmers may need to have via the mobile artifact. This chapter also included a discussion on how these insights have helped to enhance the current tool. This chapter also discussed on how the current decision-making process can be enhanced by providing different type of knowledge and implementing choices in the

MBIS. Finally, a presentation of the relationship between choice and empowerment outcomes was provided. This chapter has presented the concepts and the data captured that laid the foundation for development of the framework presented in the following chapter.

5 Empowerment Framework and Design of Mobile based Information System (MBIS)

This chapter addresses the second research question, RQ2.

RQ2: How to design a suitable mobile artifact to empower farmers?

To address RQ2, the elements of an empowerment framework that was developed because of the insights gained in 2012 and 2013 farmer field trials in Sri Lanka will be discussed. This chapter will also discuss how the Mobile based Information System (MBIS) was designed based on the empowerment framework.

5.1 Towards an empowerment framework

The investigations that were conducted in 2012 and 2013 helped in the development of the following guidelines for creation of an empowerment-oriented artifact;

a) Identify and list meaningful goals,
b) Identify and list empowering processes,
c) Based on (a) and (b), design an empowerment model with meaningful goals, empowerment processes and empowerment outcomes,
d) Identify and list useful and motivating choices, in context, in the processes,
e) Identify and list different types of relevant, up-to-date required knowledge,
f) Based on (d) and (e), design a mechanism to provide customised knowledge.

Though these guidelines are shown as a list, the discussion in the next sections does not strictly follow the exact order as many concepts have a relationship/s to each other. The discussion on the learning and the design activities carried out in this section were related to the sub-cycles "*Rigor - Learning (3)*" of DSR and "*Design – Heuristic Search (3)*" of DSR respectively. (see Table 5-1 below).

Table 5-1 : DSR sub-cycles of RQ2 (copy of Table 3-4)

Research Question 2 (RQ2)	DSR sub-cycle
RQ2: What is a suitable MBIS (artefact) to empower farmers?	
RQ2.1 –What are the elements of an empowerment framework? d) What are the empowerment processes? e) How to enhance decision making in the empowerment processes? f) What are the different types of knowledge required to support decision making?	Rigor – Learning (3)
	Design – Heuristic search (3)
RQ2.2 – What is an enhanced empowerment model for the Sri Lankan farmers?	Design – Heuristic search (4)
RQ2.3 – How to implement choice in empowerment processes?	Rigor – Learning (4)
	Design – Heuristic search (5)
RQ2.4 – How to design the MBIS?	Design – Heuristic search (6)

5.1.1 Meaningful goals for farmers

From discussions carried out and questionnaires used to collect data in the 2012 and 2013 field trials, the following were identified as the meaningful goals for farmers (see section 4.3).

a) financial security and feeling safe

b) easy access to relevant and up-to-date information for informed decision making

c) new skills and ideas

d) an active member of the farming community

5.1.2 Identifying empowerment processes in the MBIS

One of the objectives of this study was to develop an artifact based on empowerment processes that can assist farmers to make informed decisions to achieve their goals. To identify and design empowerment processes in the artifact, it was necessary to first understand decision making in farming processes and the activities associated with them. During our field trials, we discovered that farmers have limited access to useful information. The information they use in their farming activities is often not up-to-date

or relevant. As a result, farmers make uninformed decisions that can lead to limited success or even failure at the end of a farming cycle.

5.1.3 Enhancing decision making in farming processes

When making decisions concerning welfare and quality of life, individual experiences and intuition alone are inadequate. Since complex problems usually have many related factors, traditional logical thinking can lead to sequences of ideas that are so tangled that their interconnections cannot be readily recognised (Saaty 1994). Decision making should be simple, natural and intuitive and should not require specialised knowledge. Decision making requires relevant, up-to-date and readily accessible knowledge (Saaty 1982). Decision making has a significant effect on the outcome of any process; therefore, the problem needs to be modelled creatively to meet the overall goal. In order to fulfil the overall goal, there may be sub goals that their need to be fulfilled. (Saaty 1994).

Informed decisions are very important for farmers to achieve their meaningful goals. During the field trials, the following insights with regards to how the farmers make decisions in a farming cycle and what they need so to make informed decisions were gained;

a) access to relevant information at multiple stages in the crop cycle,
b) expenses of all stages of a crop cycle,
c) customised information for personalised goals,
d) procedural knowledge that helps them to use the factual knowledge meaningfully,
e) Factual knowledge and procedural knowledge provided via different tools to support empowerment activities.

These insights were used when designing the MBIS. The objective was that the MBIS would assist farmers make better decisions at various stages of a crop cycle. One of the

important meaningful goals of a farmer is to have financial security and feel safe (see section 5.1.1). To achieve the best possible revenue at the end of a crop cycle, one of the important decisions a farmer should make at the beginning of a crop cycle is deciding which crop to grow. To make this decision, a farmer must receive information with the following attributes.

a) *Customized information* about which crops can be grown on a particular farm. The crops that can be grown depend on the soil and weather conditions of the geographical location of a farm. Therefore, if a farmer has access to a customised list of crops and selecting a crop/s from it makes sure that the selected crop/s will actually grow on the farm.
b) *Aggregated information* with regards to how much of the same crops in (a) have already been grown by other farmers in the area. It gives a farmer who is in the decision-making stage of deciding on which crop to grow, an indication of which crop is grown or not grown heavily by many other farmers.

This information assists a farmer to make informed decisions when choosing which crop/s will actually grow on their land and which will not lead to an over-supply market condition. Further, it allows a farmer to choose a crop/s that is not grown by many other farmers in the area hence benefiting from an under-supply market situation. Overall this informed decision making by farmers enables creation of a stable selling price in the market place from which all the farmers as well as consumers can benefit.

Once a farmer has selected a crop, they should carry out a cost-benefit analysis to decide whether it is financially feasible to grow. In each stage of a crop cycle there are several expenses involved (Table 4-6). To carry out an expense calculation, a farmer needs *factual information* such as quantity and cost of each item required in each stage.

In addition, a farmer should be provided with *procedural knowledge* as how to use this factual knowledge correctly. For this purpose, an expense calculator is necessary. The expense calculation provides a farmer with *the expense of each item, the expense for each stage and for the whole crop cycle.* Therefore, providing farmers with a list of crops that be grown in his/her farm, an awareness of what other farmers in the area have already decided to grow, and carrying out a cost-benefit analysis, helps a farmer to make an informed decision on which crop/s to grow at the beginning of a crop cycle. Further, this would enable a farmer to select a crop that is financially feasible to grow, which will not saturate the market, and which will produce better revenue at the end of a crop season. This can help achieve financial security in a farmer's life.

To enable the meaningful goals discussed above, three empowerment processes and four supporting processes were identified to be implemented in the artifact.

Empowerment processes:

a) Finding crops to grow
b) Calculating expenses
c) Selling the products and services of farmers

Supporting processes:

a) Viewing past expenses
b) Communication
c) Organising finances

A description of these processes is provided in section 5.4.4.

5.2 Enhanced empowerment model

This section presents the design activities of the enhanced empowerment model. It was related the sub-cycle "*Design – Heuristic Search (4)*" of DSR (see Table 5-1 above).

The meaningful goals of farmers were identified in section 5.1.1 and corresponding empowerment processes in section 5.1.2. It is important that each meaningful goal be supported empowerment and supporting processes. Table 5-2 below shows which processes address each of the meaningful goals.

Table 5-2 : Meaningful goals and empowerment processes

Meaningful goal	Empowerment process
Financial security and feeling safe	Finding crops to grow Calculating expenses Viewing past expenses Selling products/services of farmers Organising finance
Easy access to relevant, up-to-date information	Finding crops to grow Calculating expenses Selling products/services of farmers
Learn new skills and ideas	Finding crops to grow Calculating expenses Viewing past expenses Communication
An active member in the farming community	Selling products/services of farmers Communication

Empowerment outcomes are one consequence of empowerment processes. They can be used to study the effect of interventions designed to empower individuals, investigate empowerment processes and mechanisms (Zimmerman 1995). This study has considered domain-specific knowledge, perceived sense of control and self-efficacy, motivation and competence as the empowerment outcomes at the individual level of empowerment. An *initial* empowerment model for Sri Lankan farmers was created at the beginning of this research, using a scenario analysis (see Figure 4-1).

From the field trials in 2012 and 2013, an understanding was gained of how farmers work, the issues they face, their goals, how they make decisions, what information they use to make important decisions and how that decision-making process affects their final goals. These insights helped us to develop an *enhanced* empowerment model with clearly identified empowerment processes and supporting processes, how they support achievement of meaningful goals and expected outcomes (Figure 5-1).

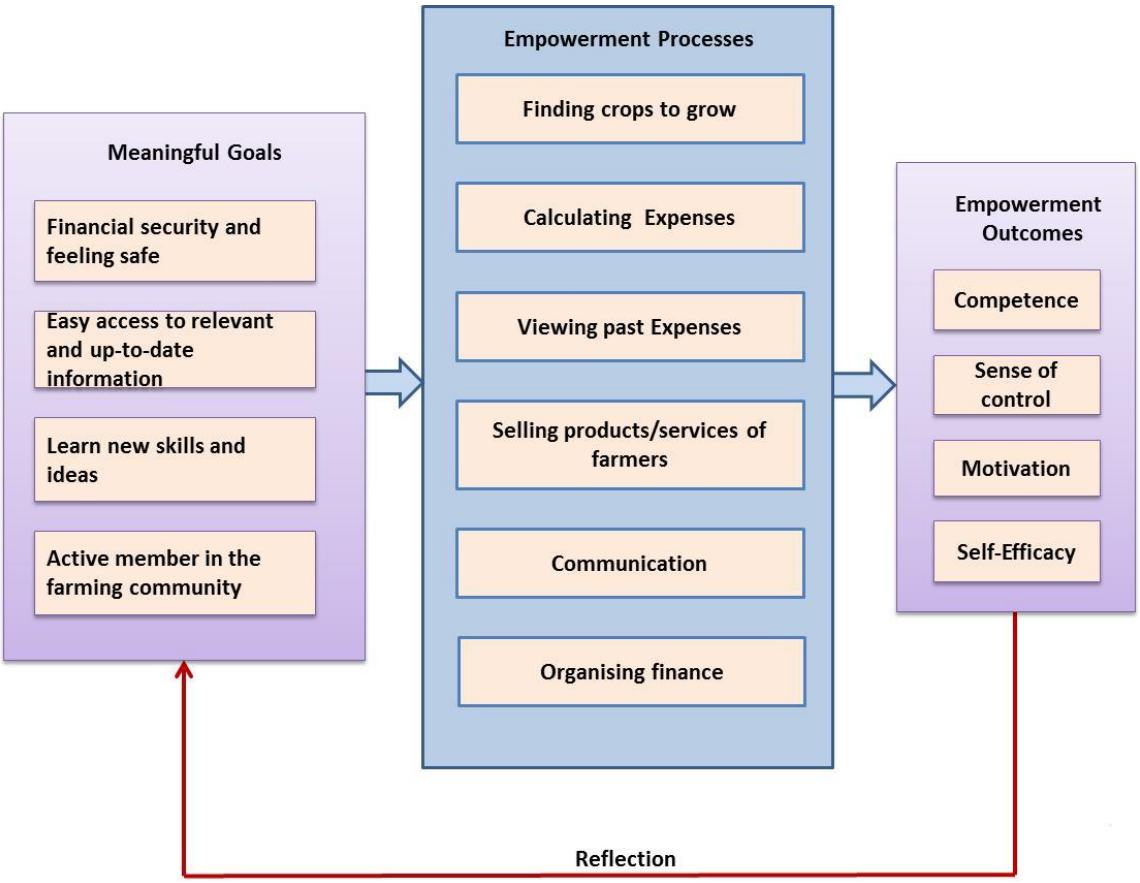

Figure 5-1 : Enhanced Empowerment model

5.3 Choice in empowerment processes

This section discusses how *choice* was embedded in the empowerment processes. The related study and the implementation of choice in the design were related to the sub-

cycles "*Rigor - Learning (4)*" of DSR and "*Design – Heuristic Search (5)*" of DSR respectively. (see Table 5-1 above).

As discussed in section 4.8.1, the exercising of choice has many psychological benefits for individuals. Sense of control is a consequence of exercising choices (deCharms 1968; Deci and Ryan 1985; Hall 1986). Research across many domains has shown that providing choice increases intrinsic motivation and competence(Deci and Ryan 1985; Deci and Ryan 2000). Depending on the self-efficacy beliefs, people can influence a choice of activities. Tasks have different difficulty levels and most people choose tasks depending on their self-efficacy beliefs (Bandura 1977; Bandura 1982). For example, an individual may choose a very difficult task because of the self-efficacy of that person that the task could be accomplished. It also gives them an opportunity to increase their sense of competence (Deci and Ryan 1985; Pintrich and Schunk 2002). Choice has the capacity to execute necessary behaviors to influence the empowerment outcomes (Bandura 1977).

Therefore, *choice* was embedded in designing the empowering processes of the MBIS to support different behaviours of the farmers; for example, for farmers to identify and engage in choice processes, learn and develop new skills, reshape a set of given choices to make them personally feasible within their specific situation, and to evaluate all the choices available and make decisions. Figure 5-2 below shows the psychological empowerment model with these attributes of behaviour. The empowerment processes were designed to support these behaviours (see sections 2.3, 4.8).

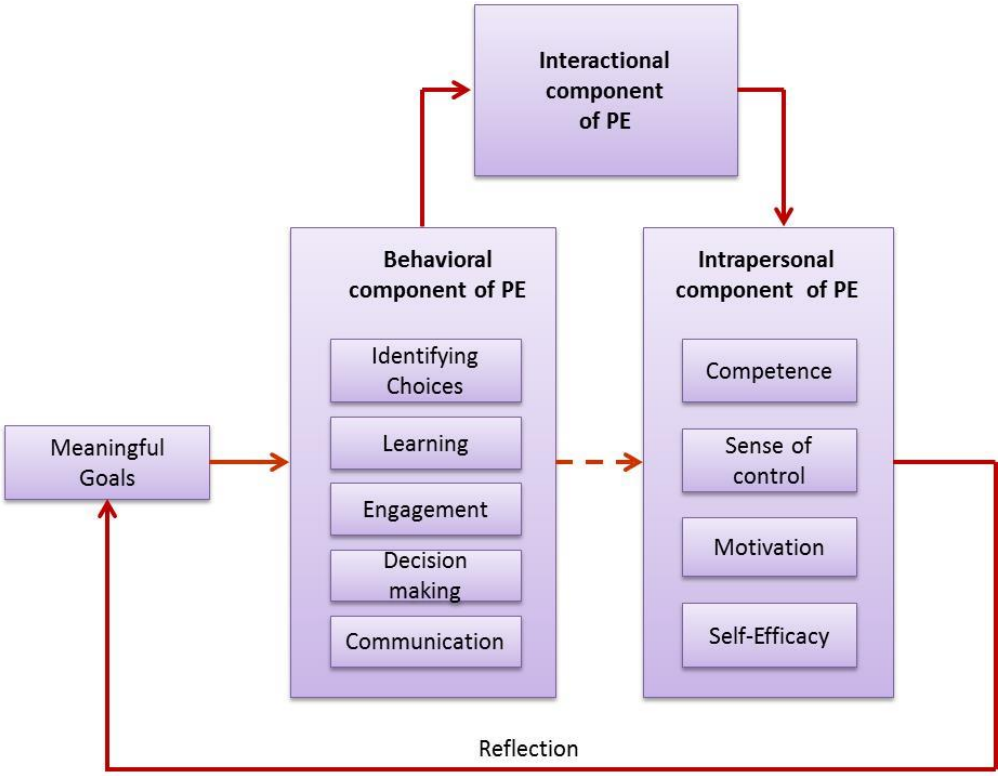

Figure 5-2 : Psychological empowerment model with attributes of behavioral component

5.4 Implementation of the Mobile-based Information System

In this section, we discuss how the MBIS was implemented, the high-level architecture of the MBIS, the design details of the tools and choice to support empowerment processes. These details of the implementation seek to facilitate an understanding of how empowerment was designed in the MBIS based on the empowerment framework. These design activities were related to the sub-cycle "*Design – Heuristic Search (6)*" of DSR (see Table 5-1).

5.4.1 High level architecture of MBIS

Figure 5-3 below illustrates the context data flow diagram of the Mobile-based Information System. It interacts with four external entities: farmer, supplier, agriculture ontology and geographical information system. The details of these entities are discussed in the following sections.

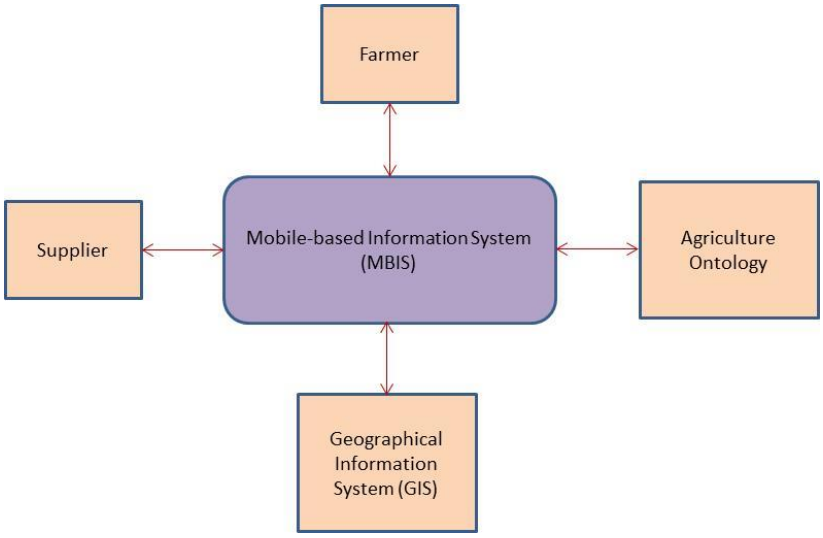

Figure 5-3 : Context Data Flow Diagram of MBIS

Figure 5-4 below shows the design of the high-level architecture of the MBIS. It has three major areas: mobile front-end, an application server consisting of the farmer application and back-end data management, and the Agriculture Ontology. For farmers, the mobile front-end is the interface between them and the MBIS. Farmers interact with the application via the tools on the mobile front-end.

5.4.2 Detailed design of MBIS

In this section, the functions identified in Figure 5-4 are discussed in detail. In the design, there are two types of functions: general functions that support the overall functionality of the MBIS, and the functions that support empowerment.

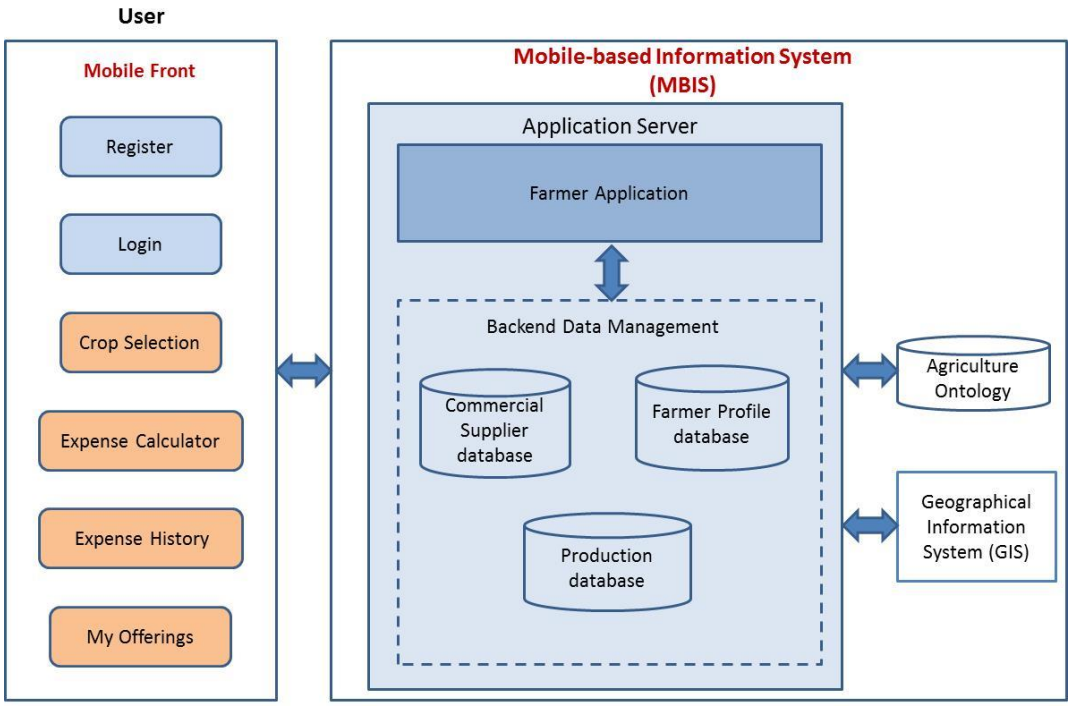

Figure 5-4 : High Level Architecture of the MBIS

The context data flow diagram (see Figure 5-3 above) was expanded to produce level-1 DFD diagram of MBIS. This shows various processes, external entities, relationships, the data flow between processes and entities (see Figure 5-5 below).

To describe the design details of both general and empowerment oriented functions, Figure 5-5 will be used. In addition, mobile interfaces that were designed for the mobile artefact will be used in the following discussions.

General Functions: The *Register* and *Login* functions on the mobile-front and backend data management functions of the application are important for the overall functionality of the MBIS. Both Figure 5-4 and Figure 5-5 will be used to describe their functionalities.

- *Empowerment-oriented functions*: Processes such as *Crop Selection, Expense Calculator, Expense History* and *My Offering* will be discussed in section 5.6.2.2.

5.4.3 Design details of general functions

- Register: A new farmer must first register with the application using the farmer's Sri Lankan national ID number, the mobile number and name of the farmer (see process 1 in Figure 5-5, Figure 5-6, Figure 5-7 below). The application sends an SMS with a pin number to the farmer's mobile phone to establish that it is a valid mobile number (see Figure 5-8 below). The farmer registration process allocates each farmer a farmer_ID and stores it in the Farmer Profile Database. This registration process enables identification of farmers and provides required customised information in other processes in the application.

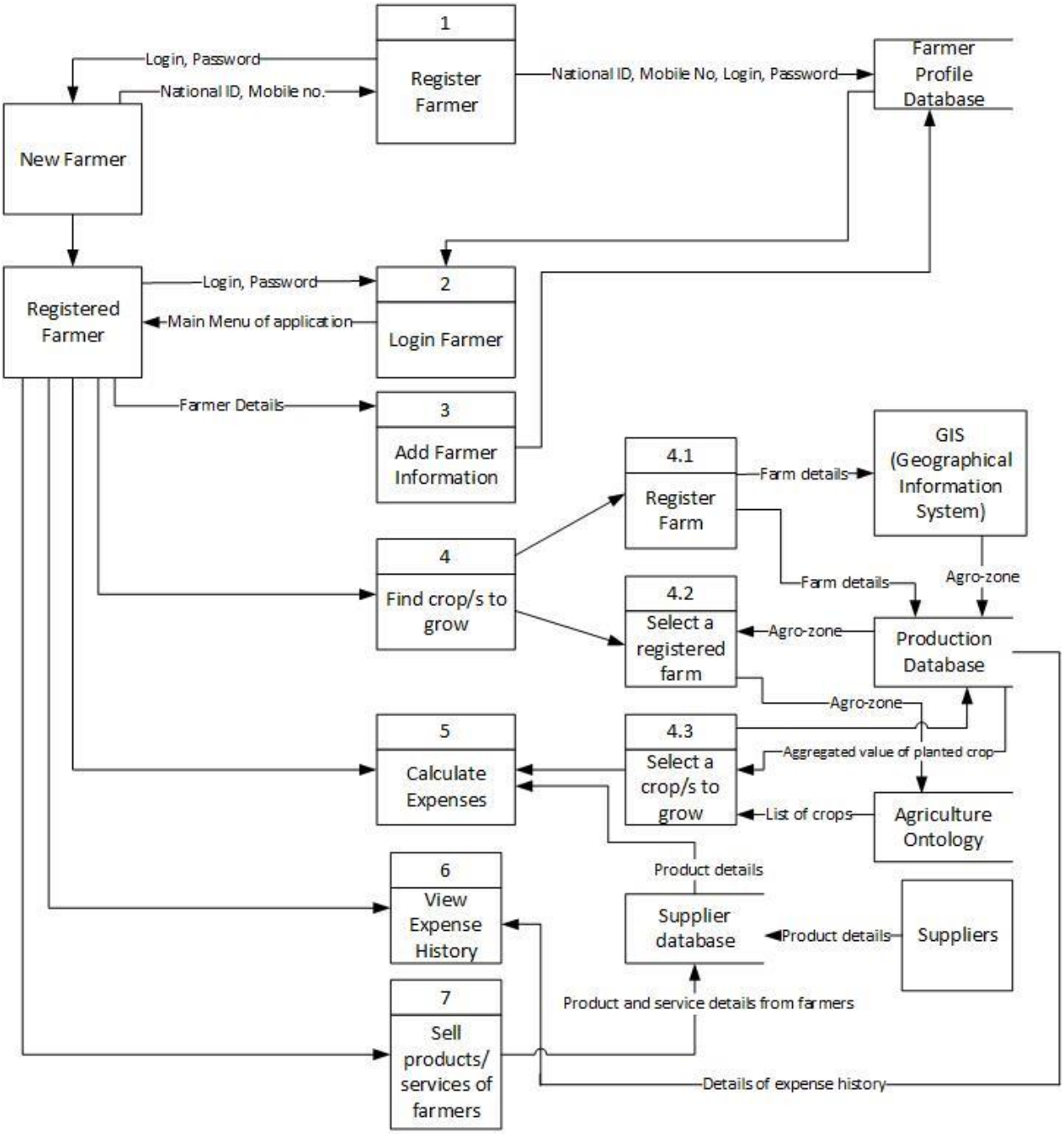

Figure 5-5 : Level 1 DFD diagram of MBIS

Mobile interfaces for farmer registration are shown in Figure 5-6, Figure 5-7and Figure 5-8 below.

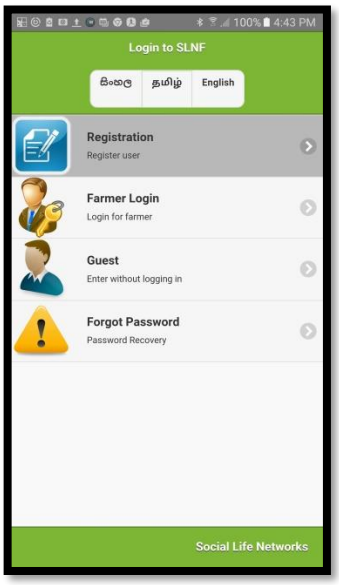

Figure 5-6: Farmer registration screen

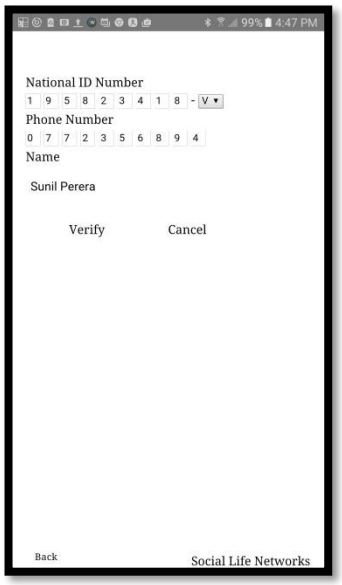

Figure 5-7 : Farmer registration screen with required information

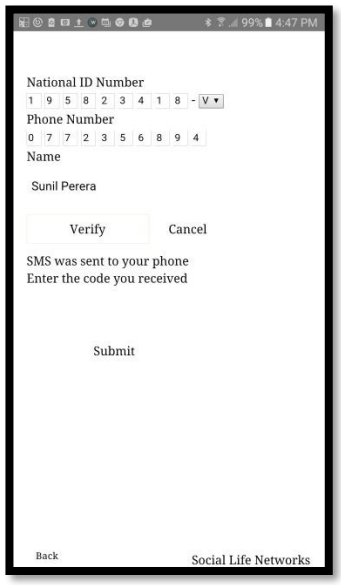

Figure 5-8 : Farmer registration verification screen

- *Login*: A registered farmer will use *the phone number* and *pin number* to login to the application for future visits (process 2 in Figure 5-5 above) and the *farmer_ID* will be used to manage data and activities associated with a farmer.

  Mobile interfaces for farmer login process are shown below. Once a farmer successfully logs on to the system (Figure 5-9, Figure 5-10 below), farmer will be navigated to the Main Menu of the application (Figure 5-11 below).
- *Farmer Profile database*: The details of a farmer are stored in the *farmer profile database.* A farmer can use *My Information* tool on the mobile front-end to edit their personal information when necessary (process 3 in Figure 5-5 above).
- *Agriculture Ontology*: This 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 (Figure 5-4 above). In addition, it has details of fertiliser, pesticides and other chemicals, and the amounts that need to be applied in different stages of a crop cycle (see Appendix F for the details of the Agriculture Crop Ontology).

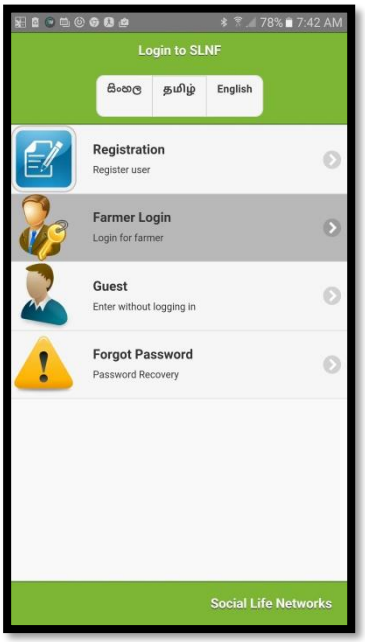

Figure 5-9: Farmer Login Screen 1

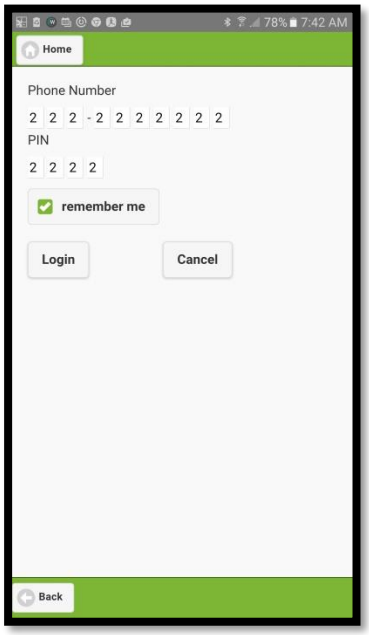

Figure 5-10 : Farmer Login Screen 2

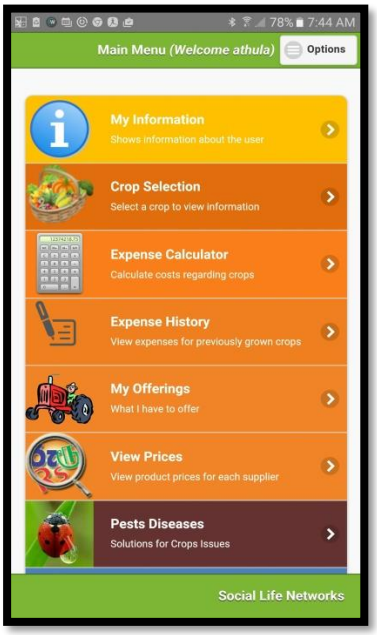

Figure 5-11 : Main Menu of the application

- *Production database*: The data entered by a farmer, such as the size of a farm and the extent of a crop that is grown, are stored on the production database (Figure 5-4 above). In addition, expense calculations that a farmer carries out are also stored in the production database.
- *Commercial Supplier Database*: 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.
- *Geographical Information System (GIS)*: After a farmer is registered, geographical coordinates are sent to the GIS. It will compute the corresponding agro-zone of the farm. The information in the Agriculture Crop Ontology is stored according to the agro-zones of Sri Lanka. The agro-zone value enables provision to farmer of a list of crops that can be grown in his/her farm.

5.4.4 Design details of empowerment-oriented processes

Figure 5-12 below, shows the enhanced empowerment model with empowerment processes and supporting tools and data management. In the following discussion, both Figure 5-12 and Figure 5-5 (above) will be used to describe the functionality of the empowerment processes and the system as a whole.

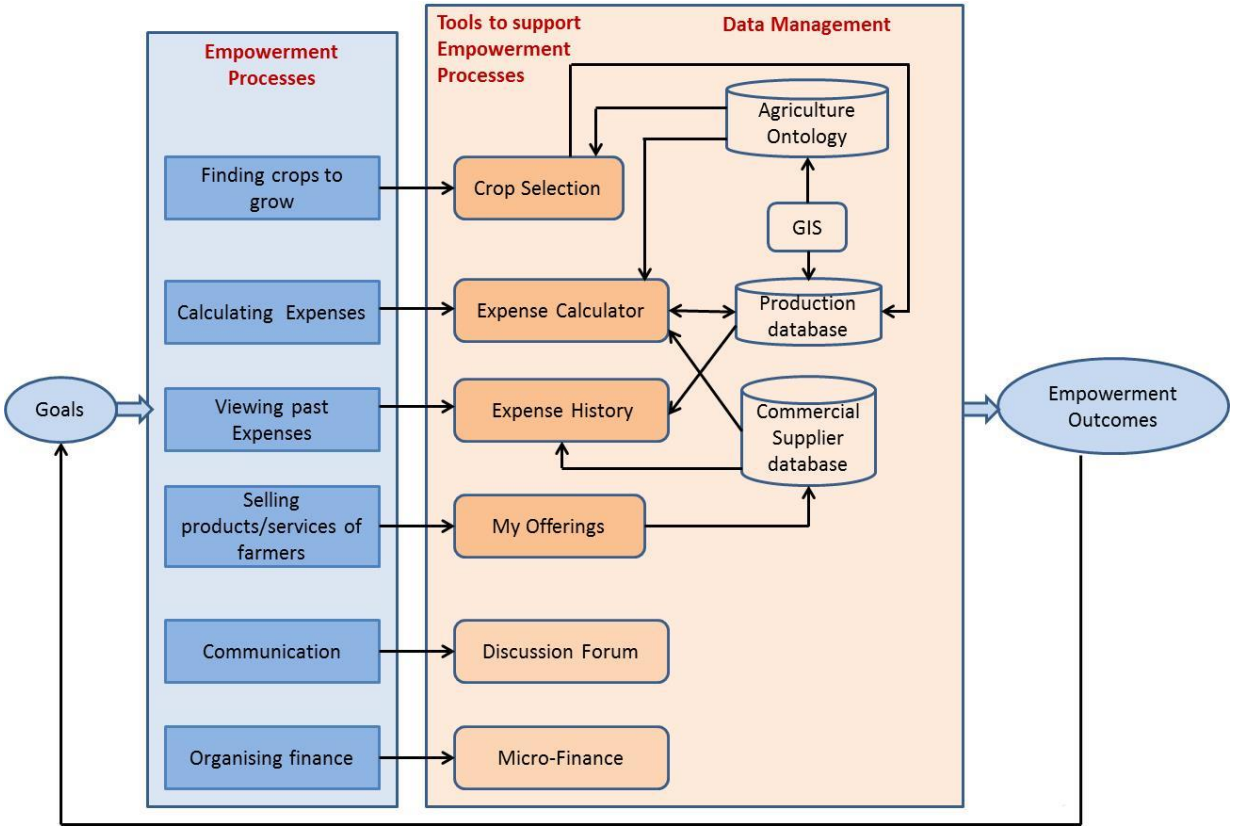

Figure 5-12 : Enhanced empowerment model with empowerment processes and tools

5.4.4.1 *Finding crops to grow* empowerment process

This is the most important process in the whole crop cycle. It is where farmers make the critical decision on which crop/s to grow. This process is supported by the *Crop Selection* tool (Figure 5-12 above and process 4 in Figure 5-5 above). It initiates the activities that help a farmer to select which crop/s to grow in a farming season. In the

crop selection process, a farmer receives a list of crops that grow in a selected farm, creates a *short list of crops*, performs necessary expense calculations and finally decides on which crop/s to grow. Each farm can have a long 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. To use this application meaningfully, a farmer needs at least one registered farm. Therefore, the first step in the crop selection process is to either register a new farm (see process 4.1 in Figure 5-5 above) or select an already registered farm (see process 4.2 in Figure 5-5 above).

The mobile interfaces for registering a farm are shown in Figure 5-13 and Figure 5-14 below. The *Crop Selection* tool in the main menu of the application (Figure 5-11 above) directs a farmer to the screen that allows the registration of a new farm using the "Add Farm" function (Figure 5-13). When registering a farm, the farm must be identified by a name (Figure 5-15 below). The location of the farm is then entered using either the addressing details of the farm (Figure 5-14) or the map (Figure 5-16 below). Farmers can add any number of farms.

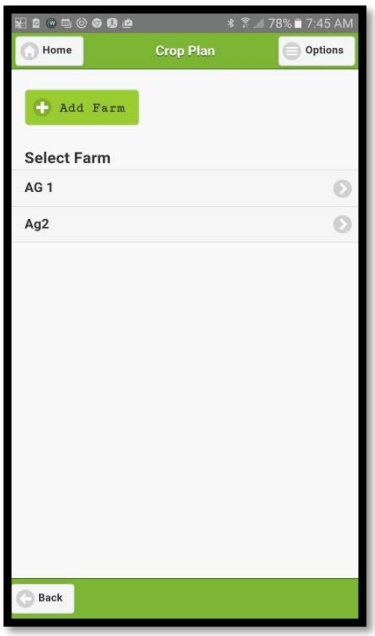

Figure 5-13: Farm Registration screen

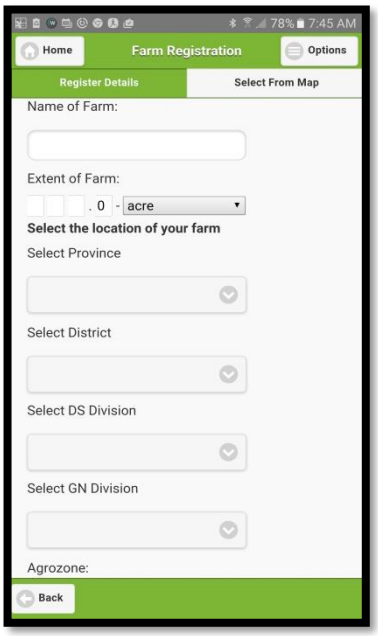

Figure 5-14 : Farm Registration using farm address

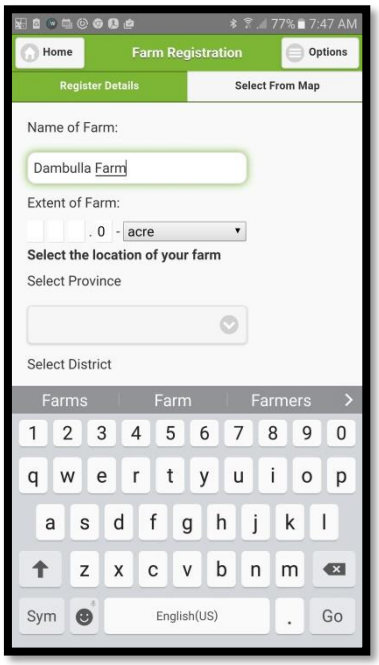

Figure 5-15 : Farm registration with farm name

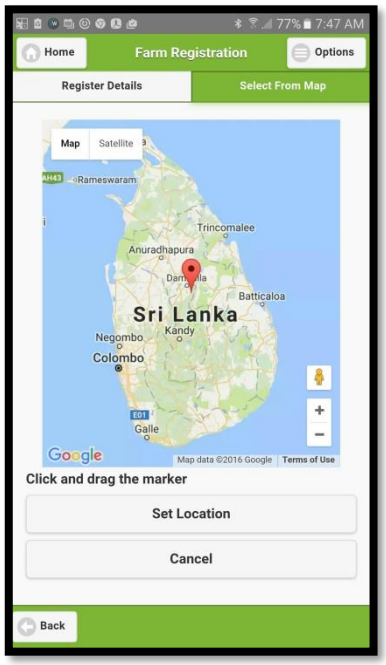

Figure 5-16 : farm Registration using the map

Once a new farm is registered or a registered farm is selected, the Geographical Information System (GIS) computes the agro-zone value of the farm and sends the agro-zone value of the selected farm to the Agriculture Ontology. The Agriculture Ontology then

sends the farmer a list of crops that can be grown in the selected farm. Figure 5-17 and Figure 5-18 below show a list of crops that can be grown in a selected farm.

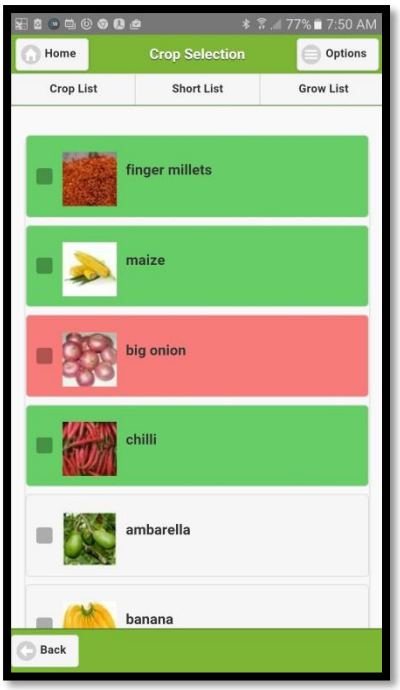

Figure 5-17 : List of crops grown in the selected farm - screen 1

Figure 5-18 : List of crops grown in the selected farm - screen 2

The list of crops screens (Figure 5-17, Figure 5-18) display the name of the crop and an indication of how much of that crop is currently being grown by the other farmers using a colour code. The total planted extent of a crop is computed by using a statistical aggregation method. For this calculation, the extent of a crop (i.e. the area) that a farmer finally decides to grow will be used (Figure 5-23). The aggregated value of a crop production is stored in the production database (process 4.3 in Figure 5-5). Rather than providing a quantitative value, the aggregated planted crop amount is displayed using a colour code: *red – high production, yellow – medium production, green – low production and white – not enough data* to statistically compute a value.

What a farmer requires is an indication of the current production level of a crop at the time of decision making process. For example, *big onion* is in high production level (Figure 5-17), *pumpkin* is in medium production level (Figure 5-18) and *tomato* is in low production level (Figure 5-18). This awareness of current production levels helps a farmer to make an informed decision that can result in a better income at the end of a farming cycle.

Each crop may contain several varieties. For example, when a farmer selects *tomato* from the list of crops (Figure 5-18 above), the application displays a list of tomato varieties (Figure 5-19). When a variety is selected the application displays the basic features of that variety. For example, when T 146 variety of tomato is selected, the application will display the basic features of T 146 (see Figure 5-20 below).

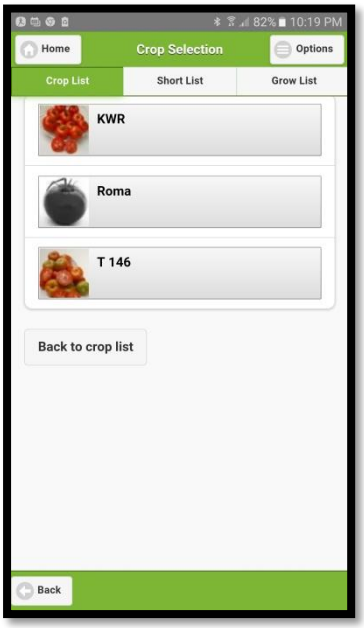

Figure 5-19 : A list of variety of a crop

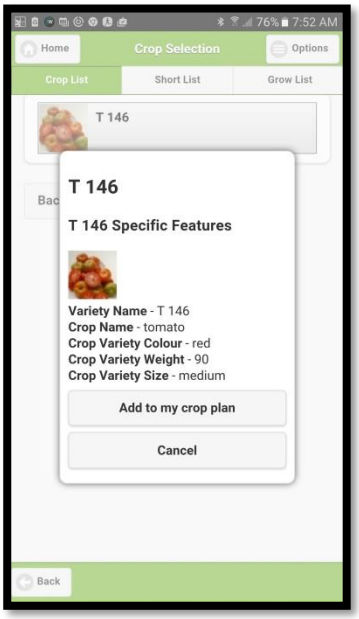

Figure 5-20 : Specific features of a variety

If a farmer would like to grow the selected crop, it will be added to the *crop short list* (Figure 5-21). For the crops in the crop short list, the farmer can carry out an expense

calculation. To start the expense calculation, the intended extent of harvest for the selected crop should be specified (Figure 5-22 and Figure 5-23 below).

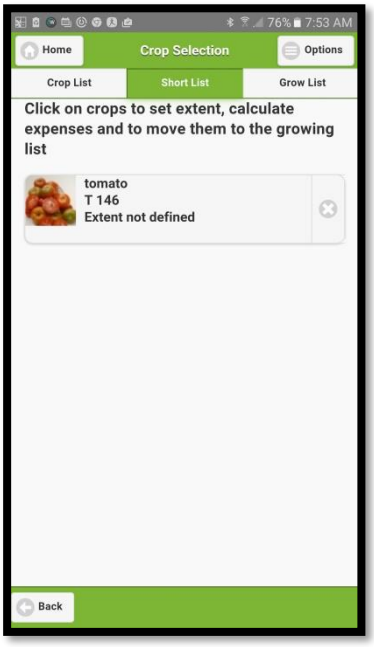

Figure 5-21 : Specify extent for the selected crop - screen 1

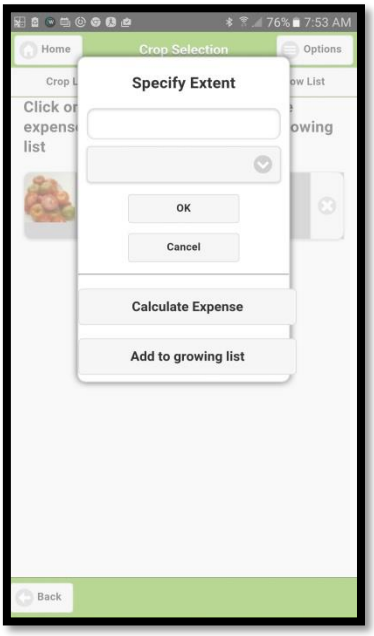

Figure 5-22 : Specify extent for the selected crop - screen 2

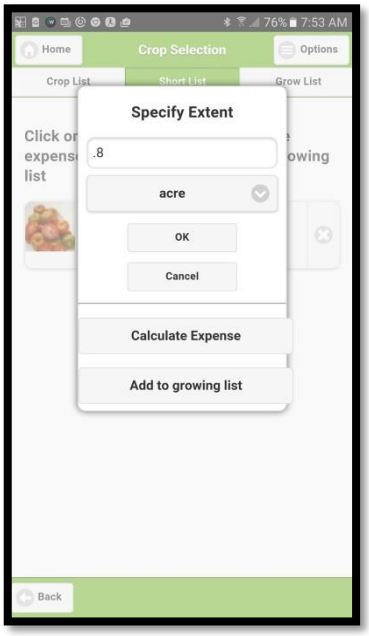

Figure 5-23 : Specify extent for the selected crop - screen 3

5.4.4.2 *Finding crops to grow* empowerment process - Implementing choice and providing knowledge

Figure 5-24 below shows the design of the *finding crop/s to grow* empowerment process. It was designed to provide choices and knowledge to facilitate informed decision making. Once a farmer has selected a registered farm, the application can provide a list of crops that can be grown in the farm (Figure 5-17, Figure 5-18 above). As discussed in section 5.4.4.1, this list of crops is customised to the farm selected. The farmer selects a crop from this list (C1 in Figure 5-24 below, Figure 5-19 above) and studies the information of the selected crop (K1 in Figure 5-24 below, Figure 5-20 above). This provides choices to the farmer to select between and knowledge to evaluate. From this knowledge, the farmer decides whether to add this crop to a "short list" and explore further details of the selected crop (D1). This process will be repeated if a farmer wants to add more crops to the "short

list" (D2). Therefore, the design of "Finding to crops to grow empowerment process" provides a farmer an opportunity to become aware of all the crops that can be grown in the farmer's land, choose several crops from that list, learn and review relevant factual agricultural knowledge of these crops, and make an informed decision on which crops a farmer may want to grow.

On completion of creating a "short list", the application then navigates to the next process – Calculating Expenses.

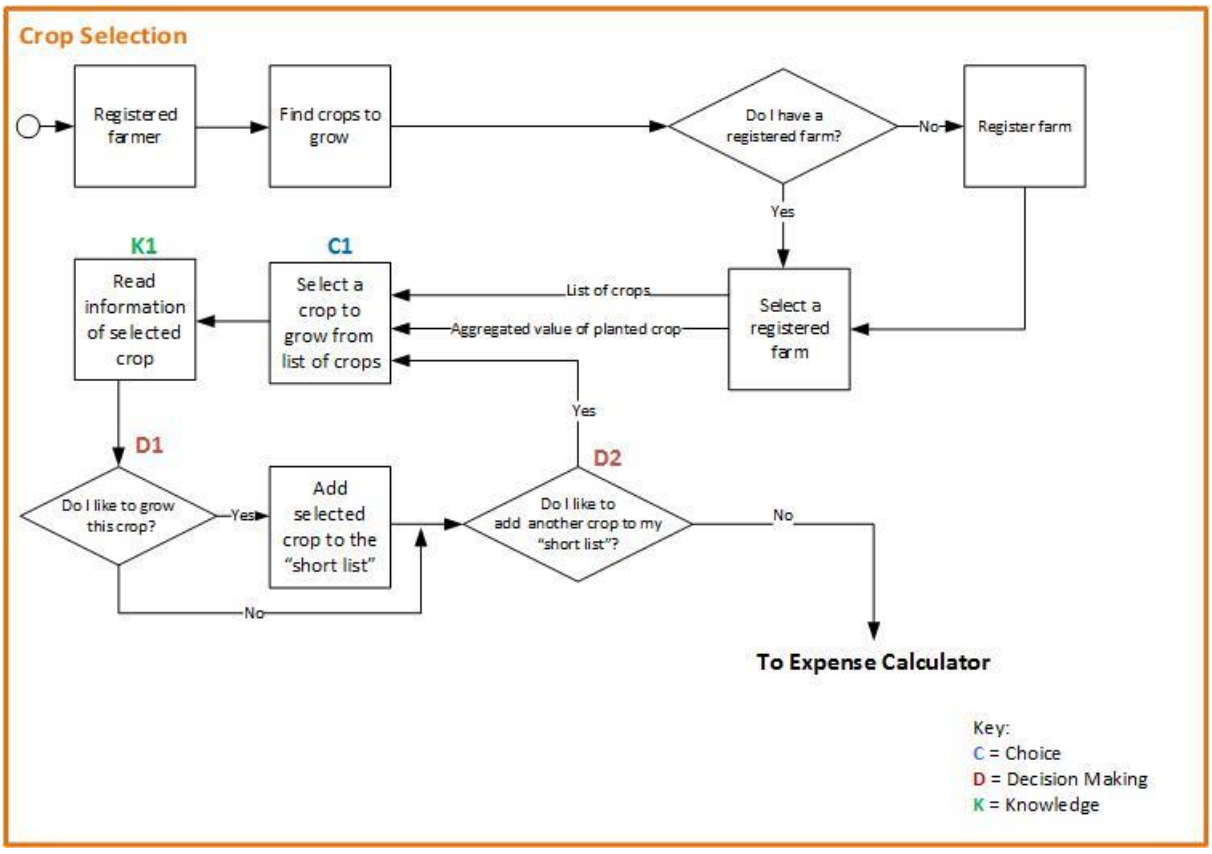

Figure 5-24 : Implementing choice and knowledge in *Finding Crops to grow* process

5.4.4.3 *Calculating Expenses* empowerment process

This process facilitates the *Finding crops to grow* empowerment process as shown in (Figure 5-12 above). It is supported by the *Expense Calculator* tool that performs the expense calculations associated with each stage of a crop cycle (process 5 in

Figure 5-5 above). The activities of a crop cycle where an expense is incurred are shown in Table 4-6.

Once a crop is short listed and intended extent for that crop is specified (Figure 5-23 above), by applying the default information, the application calculates the approximate expense of growing the selected crop and provides a summary of cost of all stages of the crop cycle (Figure 5-25, Figure 5-26 and Figure 5-27 below).

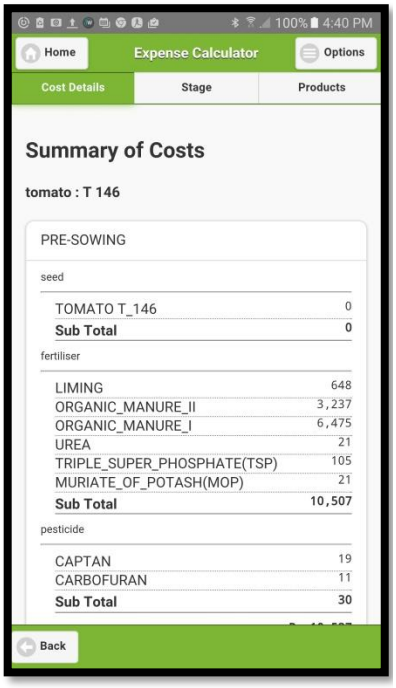

Figure 5-25 : Summary of costs - screen 1

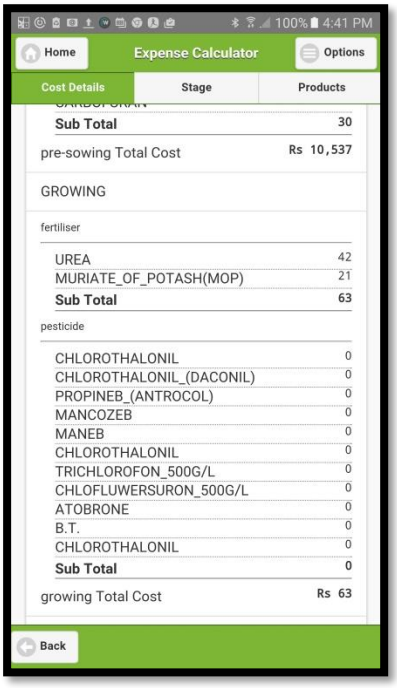

Figure 5-26 : Summary of costs - screen 2

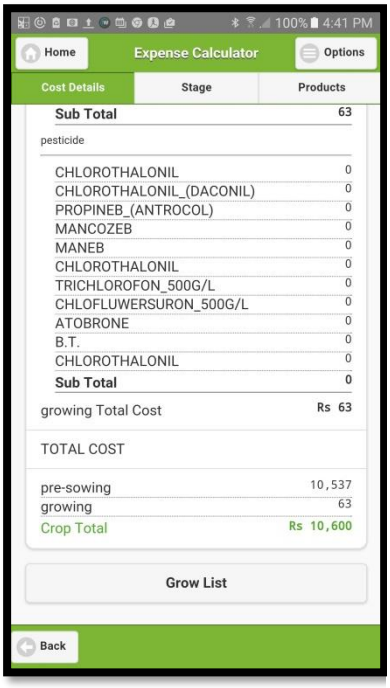

Figure 5-27: Summary of costs - screen 3

If a farmer would like to investigate the expense calculations in detail and look at various choices available, they can click on the *stage* tab on Expense Calculator screen (Figure 5-27 above).

Figure 5-28 below shows the stages of a crop cycle. Each stage of a crop cycle has different expense items (Table 4-6). Once a stage of a crop cycle is selected, the Agriculture Ontology provides the farmer a list of expense items that are associated with the selected stage. This includes type and the quantity of fertiliser,

pesticide, chemicals and any other necessary information required to calculate the expense. For example, Figure 5-29 below shows the different expense items in the *pre-sowing* stage. When a farmer chooses *fertiliser*, the application displays different types of fertiliser required (Figure 5-30 below). When a type of fertiliser is chosen, the application displays the recommended quantity of fertiliser and a list of suppliers who sell that fertiliser (Figure 5-31 below).

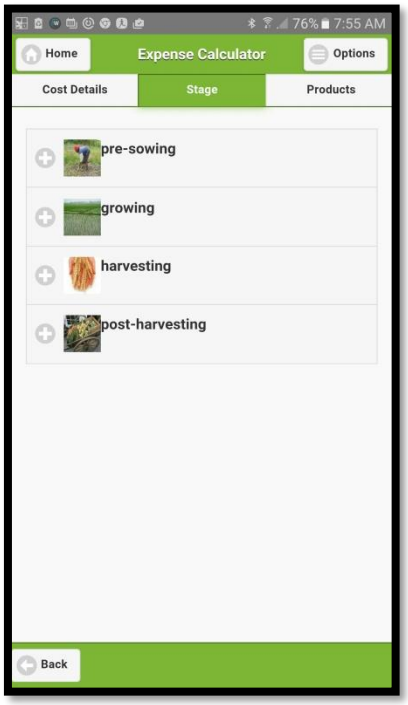

Figure 5-28 : Stages of a crop cycle

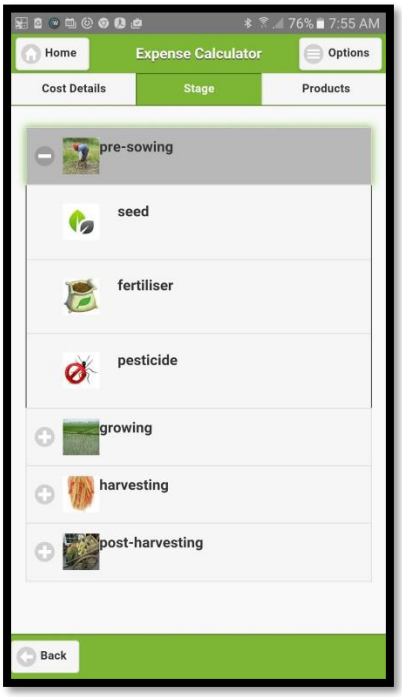

Figure 5-29 : Expense items in pre-sowing stage

The *Expense Calculator* is linked to a list of suppliers who sells these items with their sale prices and contact details. When a farmer selects an item sold by a supplier, the *Expense Calculator* tool computes the expense of the selected item and updates the expense of the selected stage and the whole crop cycle. This information helps a farmer to see the effect of the expense of a chosen item on the total cost.

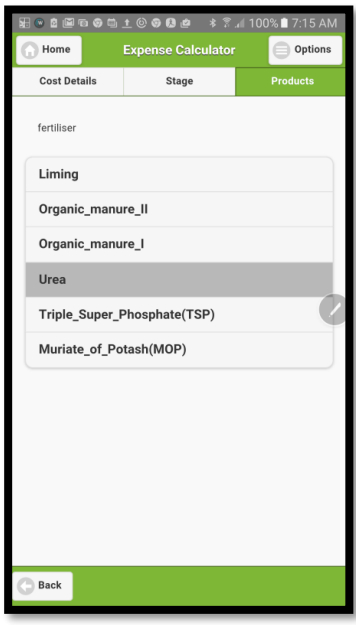

Figure 5-30 :Required fertiliser in pre-sowing stage for a selected crop

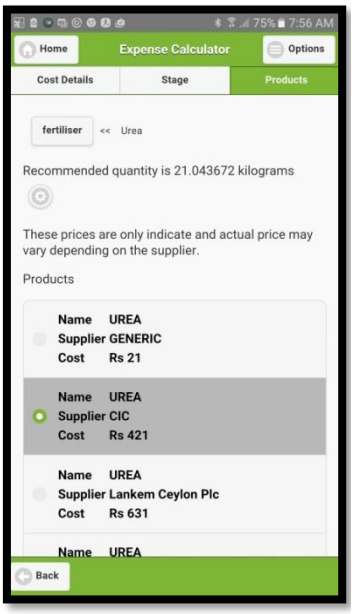

Figure 5-31 :Price of a selected fertiliser item from different suppliers

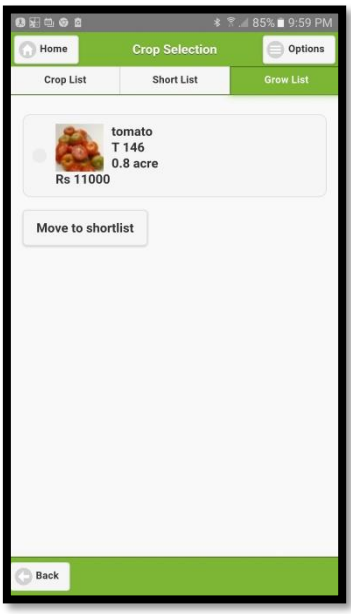

Figure 5-32 : Final decision on crop selection

A farmer can carry out this expense calculation for each item in each stage. This guided computation assists a farmer to receive an approximate idea about their expenses and make an informed decision on which crop to grow in a new farming season. Once a farmer has finally decided on which crop to grow, the value of the intended extent (quantity) will be sent to the production database to compute the aggregated value of the planted crop in the area. The name of the chosen crop will be added to the *grow list* and detailed information about how to grow this crop will be provided to the farmer (Figure 5-32 above).

5.4.4.4 *Calculating Expenses process* - Implementing choice and providing knowledge

As shown in Figure 5-24 above, after a short list of crops is created in the "*finding a crop to grow*" process, a farmer carries out a cost-benefit analysis in the "*calculating*

expenses" process. The farmer starts this process by choosing a crop from the *short list* that has already been created (C2 in Figure 5-33 below).

After entering the intended extent of growing (Figure 5-23 above), the farmer selects the stage of the crop cycle to find out the expense details for that stage (C3 in Figure 5-33 below, Figure 5-28 above). The application provides a farmer with a list of products that are needed for the selected stage (Figure 5-29 above). The farmer studies this list of products (K2 in Figure 5-33 below) and selects a product (C4 in Figure 5-33 below, Figure 5-30 above). When a product is selected, the farmer chooses the quantity recommended by the application or enter an alternative quantity (D3 in Figure 5-33 below). The application then provides a farmer a list of suppliers who sells this product with the selling price and their contact details (K3 in Figure 5-33 below, Figure 5-31 above). The farmer selects a supplier from this list (C5 in Figure 5-33 below) and the application computes the expense of the selected product, updates the expense of the selected stage and that of the whole crop cycle (K4 in Figure 5-33 below).

The farmer can decide to repeat the procedure for all the products of the selected stage (D4 in Figure 5-33 below) and the whole crop cycle (D5 in Figure 5-33 below). At the end of this expense calculation, a farmer is aware of an approximate expense involved in growing a crop.

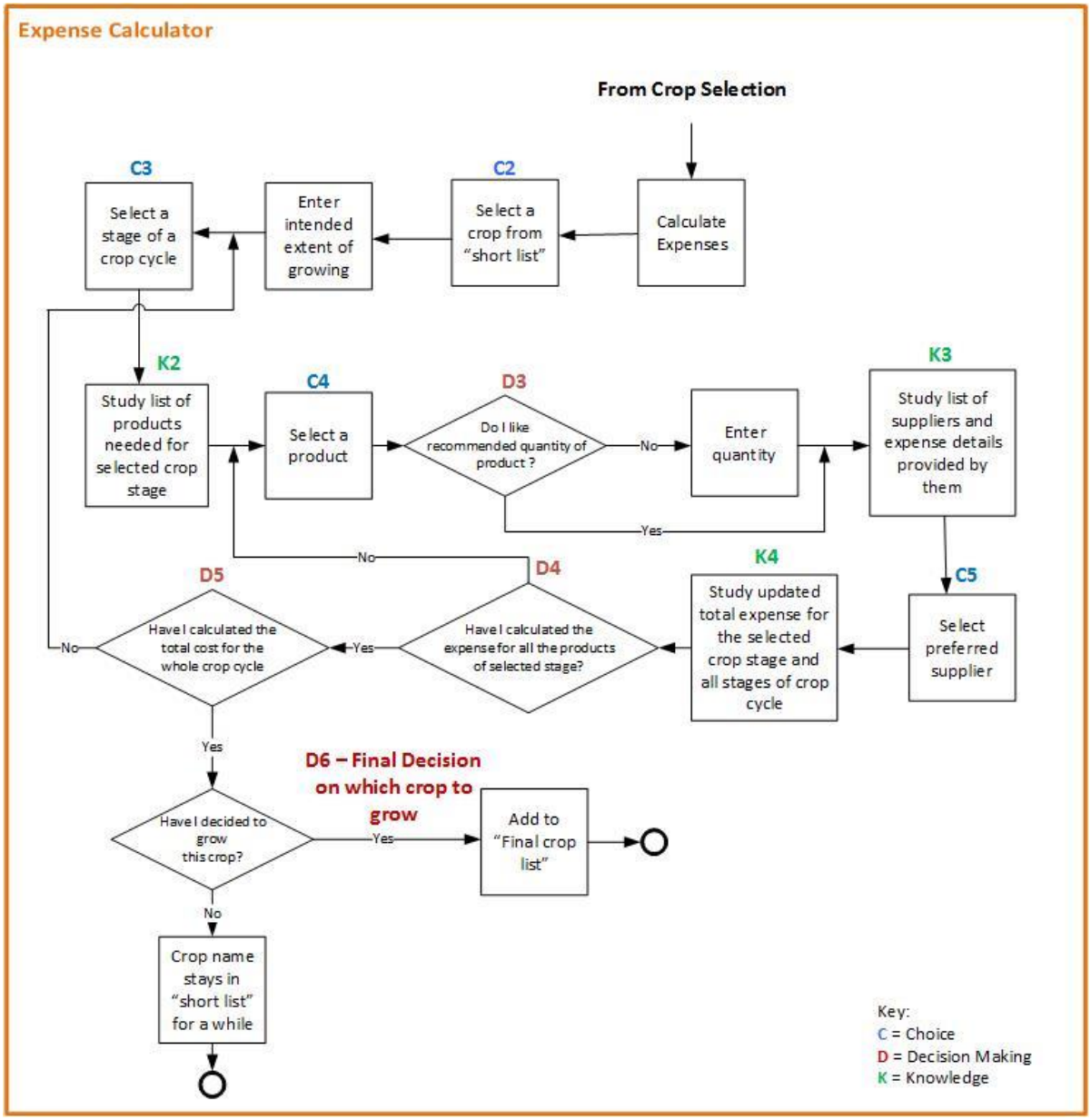

Figure 5-33 : Implementing choice and knowledge in Calculating Expenses process

The expense calculator is designed to provide choices to select a crop from a short list, choose a stage of a crop cycle, understand all the products and their quantities needed for a chosen stage, become aware of the suppliers who sells the products and their selling prices, choose a supplier, and understand the cost involved in each stage of growing a crop. Further, a farmer can choose different products and suppliers to analyse how it impacts the expense total. This systematic computation

of the expense helps a farmer to make a final decision on which crop to grow in a new farming season. (D6 in Figure 5-33, Figure 5-32).

5.4.4.5 Selling products / services of farmers empowerment process

One of the important user requirements revealed in the 2013 field trial was to provide farmers with an avenue to sell their products and services via this application. This requirement was implemented via the *My Offering* function in the application (Figure 5-12 above).

From the main menu of the mobile application, the *My Offering* function can be selected (Figure 5-34 below). Farmers can sell their products such as harvest, seeds, fertiliser, and pesticide and advertise their services such as labour, equipment hire through *My Offering* function (Figure 5-35 below). The application allows a farmer to enter the details of a product or service (Figure 5-36 below) and display a history of offerings (Figure 5-37 below). Farmers who offer their products and services to become suppliers and are added to the supplier database to make them known to the farming community (process 7 in Figure 5-5 above).

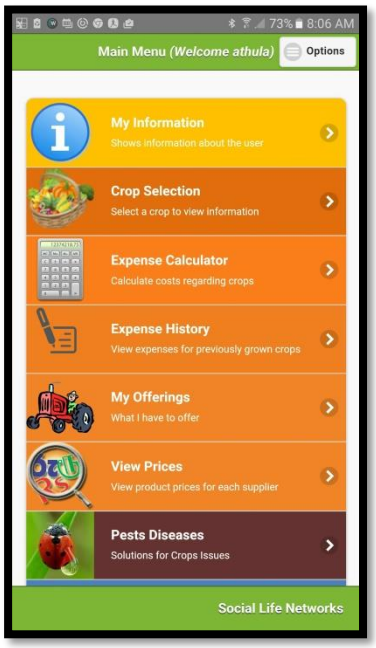

Figure 5-34 : Main Menu of the application

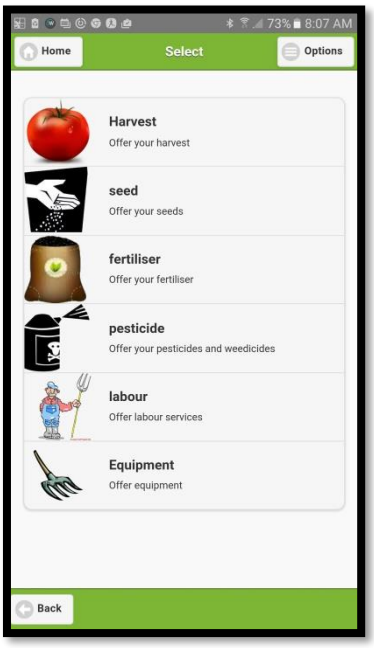

Figure 5-35 : Products and services offered by the farmers

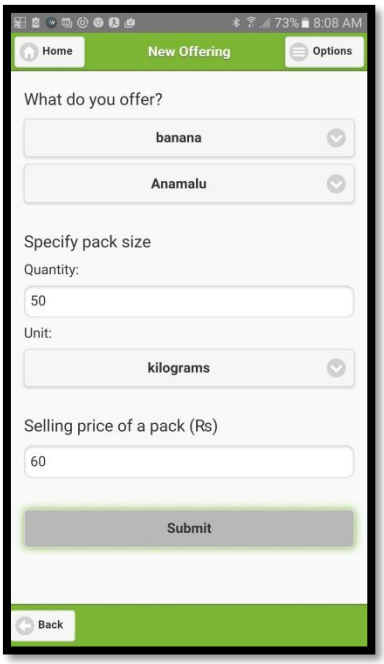

Figure 5-36 : Details of an offered product

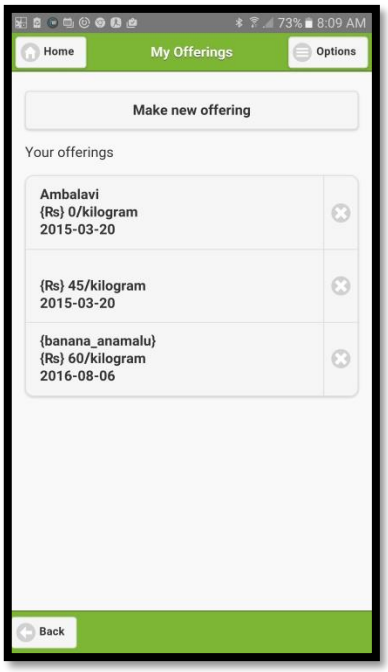

Figure 5-37 : List of offering

5.4.4.6 *Selling products / services of farmers process* - Implementing choice

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. When a registered farmer enters this process, they can view past offerings first to remember the details of what was offered previously. To add new offerings, the farmer selects a stage of a crop cycle (C1 in Figure 5-38 below) and then decides to offer a service or product (D1 in Figure 5-38 below). For each stage, the farmer can offer different products such as harvest, fertiliser, seed, pesticide and services such as labour and equipment hire (C2 in Figure 5-38 below).

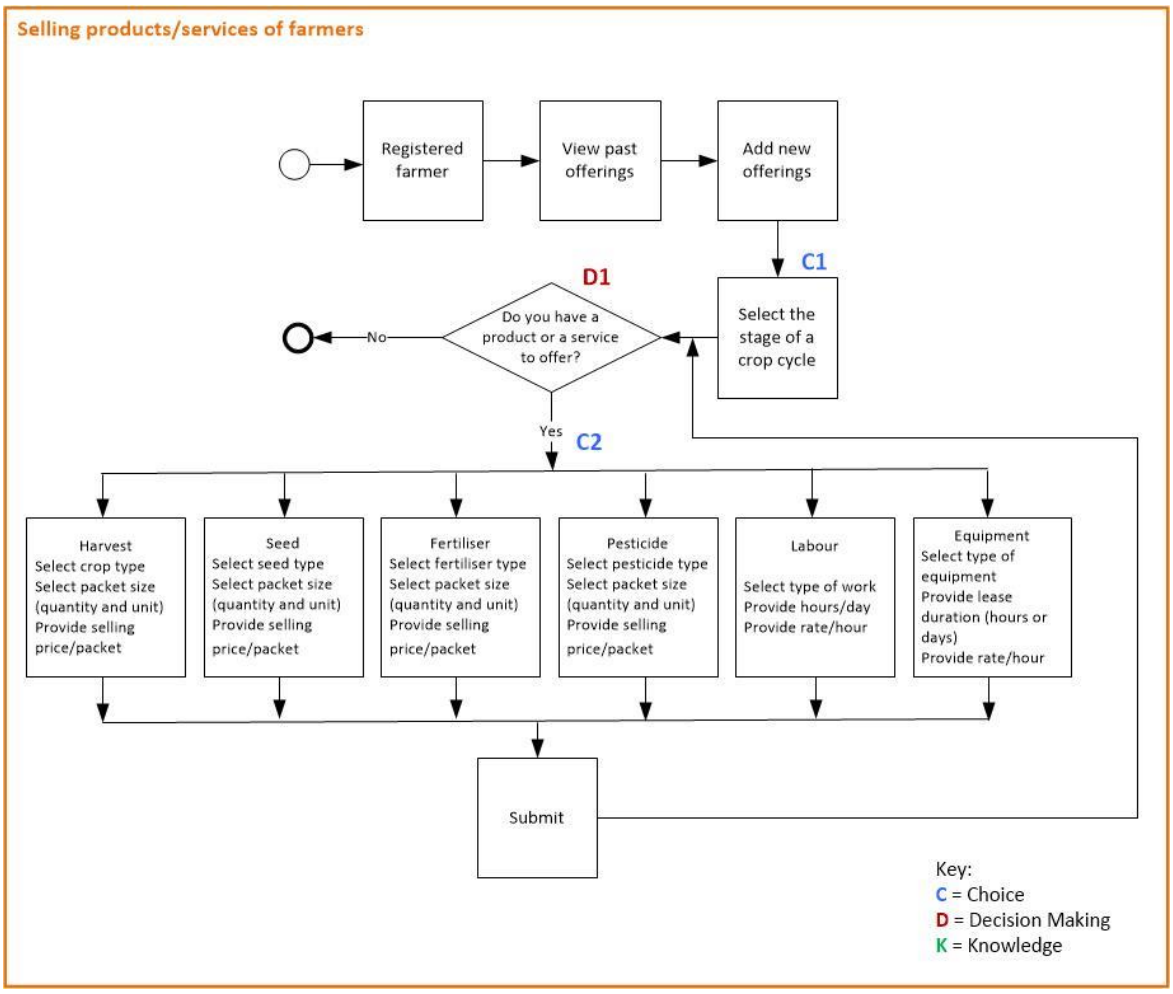

Figure 5-38 : Implementing choice in selling products / services process

5.4.4.7 Other supporting processes

The following processes support the empowerment processes described earlier.

- *Viewing Past expenses process*: This facilitates the *finding crops to grow* process. This process invokes a tool called *Expense History* in the application (Figure 5-12 above). Whenever a farmer makes a final decision on which crop/s to grow in the *Finding Crops to Grow* process, the final expense calculation is saved on the *Production Database* of the application (process 6 in Figure 5-5 above). A farmer can view the expense history for comparison purposes when making informed decisions in a new season (Figure 5-39 below).

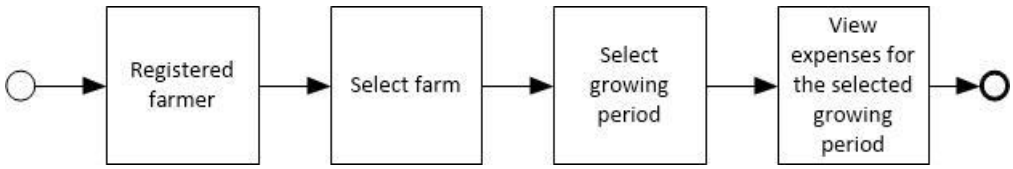

Figure 5-39 : Viewing past expenses process

- *Communication*: This process will provide farmers with a platform, such as a discussion forum, to share ideas and carry out discussions. (Figure 5-12 above. This will be implemented in the future).
- *Organising finance*: This process will provide farmers with links to banks that provide micro-finance facilities (Figure 5-12 above. This will be implemented in the future).

5.5 Summary

This chapter discussed how the mobile artefact was implemented based on the empowerment framework. To achieve meaningful goals, it is necessary to make informed decisions. The empowerment processes in the mobile artefact were designed with empowerment in mind by providing different type of customised knowledge such as

factual and aggregated. This knowledge was organised to provide farmers with choices. When designing the choices, careful attention was paid to the way they were provided. For example, mobile interfaces were designed for the farmers to easily identify, choose, select and evaluate the impact of their choices on the outcome. Therefore, when an artefact is designed with empowering processes, supported by choices and different types of knowledge, it can enable farmers to become empowered to achieve the meaningful goals in their lives.

6 Evaluation of Empowerment Framework

The goal of this research was to *develop and validate an empowerment framework for developing mobile-based applications to empower users in their livelihood activities*. This chapter discusses how our artefact, the Mobile-based Information System (MBIS), facilitates achievement of this goal.

Attributes of intrapersonal component of psychological empowerment; such as sense of control, motivation and self- efficacy were used when measuring the empowerment. These are of intrinsic value and cannot be measured directly. Therefore, existing validated instruments from the literature were investigated and three were selected to measure empowerment outcomes in the context of the agriculture domain.

In March 2015, at the beginning of a farming cycle, MBIS was deployed in Sri Lanka with 30 farmers. They were the same farmers who participated in field trial in November 2013. Farmers were provided with smart phones to access the MBIS during the farming session. At the end of the farming season in September in 2015, researchers met again with 28 of 30 farmers.

The instruments designed to measure the empowerment outcomes were used to gather data at the beginning and end of the farming cycle. The data was analysed to determine the impact on farmers' empowerment outcomes from the use of MBIS during the farming cycle.

The following subsections present the design of the instruments used to measure empowerment outcomes (Section 6.1), deployment of the MBIS and data collection (Section 6.2), results (Section 6.3) and discussion (Section 6.4).

6.1 Design of an instrument to measure empowerment outcomes

In this thesis, sense of control, motivation and self-efficacy have been proposed as the essential empowerment outcomes. The instrument used contained seven questions on Sense of Control, nine questions on Motivation and twenty-two questions on Self-Efficacy. The value of each empowerment outcome for each farmer, without the use of MBIS (*pre data*), and after the use of MBIS (*post data*), was computed using the average value. The full set of questions can be found in Appendix D.

In the following subsections, the design of an instrument to measure each empowerment outcome will be discussed. The discussion on the learning and the design of measuring instruments were related to the sub cycles "*Rigor - Learning (5)*" of DSR and "*Design – Heuristic Search (7)*" of DSR respectively. (see Table 6-1 below).

Table 6-1 : DSR sub-cycles of RQ3 (Copy of Table 3-5)

Research Question 3 (RQ3)	DSR sub-cycle
RQ3: How to evaluate the effectiveness of the empowerment framework?	
RQ3.1 – What are suitable instruments to evaluate the empowerment?	Rigor – Learning (5)
	Design – Heuristic search (7)
RQ3.2 – How to analyse responses of the farmers, pre and post MBIS?	Rigor – Learning (6)
	Relevance – Suitability validation (2)

6.1.1 Self-Efficacy

Perceived self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance and which exercise influence over 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 the efficacy levels within a domain. The self-efficacy belief system is not a

global trait but a different set of self-beliefs linked to distinct realms of functioning (Bandura 1997).

There is no all-purpose measure of perceived self-efficacy. When developing an instrument to measure self-efficacy in this study, Bandura's Guide for Constructing Self-Efficacy was employed (Bandura 2006). For measurement purposes, self- efficacy items must be created for a specific situation, and should be *valid* and accurately reflect the construct(Bandura 2006). Self-efficacy scales must be tailored to *activity domains* and assess the multifaceted ways in which efficacy beliefs operate within the selected activity domain (Bandura 1997). For example, in a farming domain there are many functional areas and stakeholders, and a farmer is one of the stakeholders. A farmer is involved in many functional areas of the farming domain such as participating in farmer association meetings, leasing a land, or carrying out farming activities during the farming season. To target the self-efficacy scales towards the agriculture domain of functioning, the *farming activities* of all stages of a farming cycle were chosen. Perceived self-efficacy should be measured against levels of task demands that represent *gradations of challenges*. Therefore, when the instrument was designed, routine farming activities such as whether a *farmer can apply various fertiliser to a crop correctly,* as well as the challenging tasks such as whether a farmer *can exercise influence to change a decision taken by government authorities* were included.

One important aspect of the instrument is the *response scale*. In the standard methodology for measuring self-efficacy beliefs, individuals are presented with items portraying different levels of task demand, which they rate in terms of the strength of their belief in their ability to execute the requisite activities. They record the strength of their efficacy belief on a 100-point scale, as defined by Bandura (Bandura 2006), ranging in 10-unit intervals from 0 ("Cannot do"); through intermediate degrees of assurance, 50

("Moderately certain can do"); to complete assurance, 100 ("Highly certain can do") (Bandura 1997) (See Appendix D).

6.1.2 Sense of Control

Sense of Control is described as the perceived degree of freedom or discretion in carrying out work activities (Hall 1986). The perception that a person is an effective agent in their own life on the one hand, as compared to the belief that one is powerless to control important life outcomes, is central to self-control (Gecas 1989). It reflects the reality of the individual's experiences, opportunities and resources (Mirowsky and Ross 1989). Some of the concepts related to a sense of control include mastery (Pearlin et al. 1981), locus of control (Rotter 1966), self-efficacy (Bandura 1997), instrumentalism (Wheaton 1980) and personal autonomy (Deci et al. 1981; Seeman and Seeman 1983).

Ryff's Scales of Psychological Well-Being (RPWB), is a widely used theoretical model of psychological well-being that encompasses 6 distinct dimensions of wellness; Autonomy, Environmental Mastery, Personal Growth, Positive Relations With Others, Purpose in Life, Self-Acceptance (Ryff and Keyes 1995). Not all the dimensions of RPMB were required for this study because the aim was to understand sense of control in the context of autonomy dimension. In RYWB there are 11 items under autonomy and out of that, 7 items were selected as appropriate for the farmers in the farming domain. (see Appendix D). The responses were coded; 1= Agree Strongly, 2 = Agree Moderately, 3 = Agree Slightly, 4 = Neither Agree nor Disagree, 5 = Disagree Slightly, 6 = Disagree Moderately, 7 = Disagree Strongly.

6.1.3 Motivation

Pinder (1998) defined work motivation as "a set of energetic forces that originates both within as well as beyond an individual's being, to initiate work-related behaviour, and to determine its form, direction, intensity and duration" (Pinder 1998, p11). Motivation can be either intrinsic or extrinsic where a person is intrinsically motivated if the desire to

change comes from within the individual. For example, a person may want to learn something because he or she is interested while another person may want to accomplish a goal or task because it is something they feel competent at and enjoy doing. On the other hand, extrinsic motivation comes from outside the person. They might be bribed to do something or they earn a prize, recognition or a reward.

In this study, the objective was to measure the motivation of farmers in general. For this purpose, The Work Extrinsic and Intrinsic Motivation Scale (WEIMS) – a measure of work motivation grounded in self-determination theory was used (Deci and Ryan 2000). WEIMS has 18 item measures of work motivation (Tremblay et al. 2009). Nine out of 18 items applicable to the farmers in the farming domain were selected. The responses were coded; 1= Agree Strongly, 2 = Agree Moderately, 3 = Agree Slightly, 4 = Neither Agree nor Disagree, 5 = Disagree Slightly, 6 = Disagree Moderately, 7 = Disagree Strongly. (see Appendix D).

6.2 Deployment of the Mobile Based Information System (MBIS) for Data Collection

In March 2015, the Mobile Based Information System was deployed with 30 farmers from our original group of 50. We had money to buy only 30 smart phones and maintain its cost each month. Therefore, a sample size of 30 farmers was randomly selected. These 30 farmers were from 6 villages in Dambulla and Pollonnaruwa in Sri Lanka. Five researchers from the Australian and Sri Lankan research groups were involved in this study and spent 4 days at these locations. The colleagues at the University of Colombo, Sri Lanka, organized the farmers to attend this study via the agricultural officers at Dambulla and Pollonnaruwa. Farmers came to the agricultural offices at Dambulla and Pollonnaruwa on allocated days. The communication of this study was conducted in the farmers' native language: Sinhala.

The deployment stage of the investigation had many activities. Each farmer was provided with a smart phone with the application installed on it. This application is available in three languages: Sinhala, Tamil and English; three commonly used languages in Sri Lanka. Most of the farmers had seen smart phones before but they did not own one. Therefore, some time was spent with each farmer to explain and demonstrate how the application worked. It gave them an opportunity to familiarise themselves with the application and ask questions.

Smart phones were provided to the farmers by the University of Colombo on the condition that they continue to use it throughout the farming session. The University of Colombo also paid the farmers' telecommunication bills during that period. Farmers were given a manual written in Sinhala that explained how to use the application. Farmers were also introduced to a technical officer who they could contact about any issues with the application and Internet connectivity.

Farmer activities on the application were logged on a server and when there was no activity recorded, the technical officer contacted them to find out if they had any issues and help to resolve them. The questionnaire that was designed (see Appendix D) was used to collect the data to measure the current level of empowerment outcomes. In total, about 1 hour was spent with each farmer to carry out these activities.

It was observed that 28 out of 30 farmers participated in the data collection activities conducted in September 2015. The same questionnaire used in March 2015 was used to evaluate the impact of MBIS on empowerment outcomes. Some open-ended questions were also used to gather farmers' experiences of using the application, understand issues with the application and connectivity, understand their views on using applications like this by the whole farming community of Sri Lanka and understand effects of it on the society. These responses were recorded on paper.

During both data collection processes, each farmer was met by a member of the research group. Each farmer was given a questionnaire to record their responses and the research member explained any questions that they found unclear. Farmers found it difficult to answer the questions that were related to sense of control and motivation. This was mainly because they were not used to expressing their feelings. They found it easier to respond to self-efficacy questions as they were related to the work they carry out in the farming.

The responses from both instruments; the Work Extrinsic and Intrinsic Motivation Scale (WEIMS) used to measure motivation (Tremblay et al. 2009), and Ryff's Scales of Psychological Well-Being (RPWB) (Ryff and Keyes 1995) used to measure sense of control, were coded as *1= Agree Strongly, 2 = Agree Moderately, 3 = Agree Slightly, 4 = Neither Agree nor Disagree, 5 = Disagree Slightly, 6 = Disagree Moderately, 7 = Disagree Strongly*. These were the original scales used in the instruments.

After the responses were collected, response code was changed by allocating a higher digit to represent a higher response. Therefore, in the data analysis process, this converted code was used*: 7= Agree Strongly, 6 = Agree Moderately, 5 = Agree Slightly, 4 = Neither Agree nor Disagree, 3 = Disagree Slightly, 2 = Disagree Moderately, 1 = Disagree Strongly*.

The responses for all the three empowerment outcomes; sense of control, motivation and self-efficacy were tabulated for each farmer as *pre-data (March 2015)* and *post-data (September 2015).* The questionnaire for each empowerment outcome consisted of several questions (See Section 6.1). For each farmer, a *pre* and *post* value for each empowerment outcome was assigned by computing the mean value of these responses. These values are provided in Table 6-2.

6.3 The Results

Several analyses were performed on the results to answer the research question RQ3: *how to measure the effectiveness of the artefact in relation to the empowerment.* This analysis process is related to the sub cycle "*Relevance – Suitability Validation (2)*" DSR. (see Table 6-1 above).

6.3.1 Analysis One – Was there a change in empowerment outcomes due to the MBIS?

One of the aims of this research was to determine whether there was a change in empowerment outcomes due to the MBIS. Table 6-2 below shows the mean values of *pre* and *post* empowerment outcomes.

To determine which statistical test is most appropriate for our data, for each measure, the levels of skew and kurtosis were used to determine if the distribution of the difference of *post* and *pre* values was normally distributed.

Table 6-2 : Pre and Post mean values of empowerment outcomes

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

Evaluating *Analysis One* data for normality

To check if the data was approximately normally distributed, several tests were conducted. These tests included (D'Agostino and Stevens 1986):

1. Skewness and Kurtosis z-values (the normality distributed variable should be in the span of -1.96 to +1.96)
2. The Shapiro-Wilk test p-value (the normality disturbed variable should be above 0.05)
3. Histograms, Normal Q-Q plots and Box plot should visually indicate the data is normally distributed.

The results of first normality test, Skewness and Kurtosis are shown in Table 6-3 below.

Results showed that Skewness and Kurtosis z-values were normally distributed for self-

efficacy and motivation. However, the Kurtosis value for sense of control was not within the acceptable normality range of -1.96 to +1.96.

Table 6-3 : Skewness and Kurtosis z-values

Empowerment Outcome	Skewness	Kurtosis z-values
Self-Efficacy	.539	-.278
Sense of Control	1.166	***3.563***
Motivation	-.455	.025

The second normality test used was Shapiro-Wilk normality. In the Shapiro-Wilk normality test, the null hypothesis test of normality is that the variable is normally distributed. The null hypothesis is rejected if the *p*-value is below 0.05. The result of Shapiro-Wilk normality as shown in Table 6-4 below reveals *p* values below 0.05 for motivation (*pre*) and sense of control (*post*). Therefore, the null hypothesis was rejected.

Table 6-4: Shapiro - Wilk normality test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Self-Efficacy (pre)	.149	28	.115	.946	28	.158
Self-Efficacy (post)	.115	28	.200*	.962	28	.394
Sense of Control (pre)	.115	28	.200*	.962	28	.381
Sense of Control (post)	.171	28	**.035**	.934	28	.078
Motivation (pre)	.168	28	**.042**	.922	28	**.038**
Motivation (post)	.103	28	.200*	.970	28	.572

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

In the final normality test, Normal Q-Q plots were plotted to check visually whether the data was normally distributed. The expected values are a straight diagonal line, whereas the observed values are plotted as individual points. If the distribution were normally distributed, then the observed values should fall exactly on the straight line. These plots indicated that the empowerment data set was not normally distributed (See Appendix E).

The above three normality tests, Skewness and Kurtosis z-values, Shapiro-Wilk test p-value and Normal Q-Q plots, indicated that the data was not normally distributed. We decided that the statistical test used to answer the research question should be therefore non-parametric. Non-parametric tests are sometimes called distribution-free tests because they are based on fewer assumptions. For example, they do not assume that the outcome is approximately normally distributed (D'Agostino and Stevens 1986).

The Wilcoxon signed-rank test was conducted to determine whether there was a significant difference between the mean values of the data collected. The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test used when comparing two related samples, matched samples, or repeated measurements on a single sample to assess whether their population mean ranks differ (Statistics 2013).

The results of Wilcoxon signed-rank test are shown in Table 6-5 below. Details of the test results are available in Appendix E.

Table 6-5 : Wilcoxon signed-rank test

Test Statistics[a]

	Self-Efficacy (pre) - Self-Efficacy (post)	Sense of Control (pre) - Sense of Control (post)	Motivation (pre) - Motivation (post)
Z	-4.601[b]	-4.160[b]	-2.374[b]
Asymp. Sig. (2-tailed)	.000	.000	.018

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

Self-efficacy Data: There was a significant difference in the mean values of Self-Efficacy (post) and Self-Efficacy (pre) data, $z = -4.601$, $p < .05$

Sense of control data: There was a significant difference in the mean values of Sense of Control (post) and Sense of Control (pre) data, $z = -4.160$, $p < .05$.

Motivation Data: There was a significant difference in the mean values of Motivation (post) and Motivation (pre) data, $z = -2.374$, $p < .05$.

Based on Wilcoxon signed-rank test results, it was concluded that there was a change in the empowerment outcome results of the farmers due to the use of Mobile based Information System.

Since the tests for normality only failed in a subset of our measures (i.e. for sense of control (*post*) and motivation (*pre*)), it was decided to check our results using a standard parametric statistical test. To compare the means of *pre* and *post* values of sense of control, motivation and self-efficacy, *dependent t-tests* were performed. The dependent t-test which is a *repeated measures* statistical test (also called the *paired t-test* or paired-samples t-test), compares the means of two related groups to detect whether there are any statistically significant differences between these means (Statistics 2013). In the *dependent t-test*, related groups indicate that the same subjects are present in both groups and each subject is measured on two occasions on the same dependent variable. The results of the t-test are shown in Table 6-6, Table 6-7, and Table 6-8 below.

Self-Efficacy: On average, there was an increase in self-efficacy outcome with MBIS (M = 76.35, SD = 8.18) and self-efficacy outcome without MBIS (M = 60.84, SD = 10.88), $t(27) = 7.93$, $p < .001$.

Sense of Control: On average, there was an increase in sense of control outcome with MBIS ($M = 5.75$, $SD = .51$) and sense of control outcomes without MBIS ($M = 5.19$, $SD = .47$), $t(27) = 6.01$, $p < .001$.

Motivation: On average, there was an increase in motivation outcome with MBIS (M = 5.69, SD = .53) and motivation outcome without MBIS (M = 5.42, SD = .55), $t(27) = 2.73$, $p < .011$.

Table 6-6 : Paired Samples Statistics

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Self-Efficacy (post)	76.34740260	28	8.182269107	1.546303516
	Self-Efficacy (pre)	60.84415584	28	10.87798194	2.055745355
Pair 2	Sense of Control (post)	5.750000000	28	.5078745002	.0959792589
	Sense of Control (pre)	5.188775510	28	.4730908188	.0894057610
Pair 3	Motivation (post)	5.698412698	28	.5305975295	.1002735078
	Motivation (pre)	5.428571429	28	.5491101716	.1037720683

Table 6-7 : Paired Samples Correlations

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Self-Efficacy (post) & Self-Efficacy (pre)	28	.439	.019
Pair 2	Sense of Control (post) & Sense of Control (pre)	28	.506	.006
Pair 3	Motivation (post) & Motivation (pre)	28	.532	.004

Table 6-8 : Paired Samples Test - Differences

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Self-Efficacy (post) - Self-Efficacy (pre)	15.50324675	10.34848802	1.955680410	11.49052201	19.51597150	7.927	27	.000
Pair 2	Sense of Control (post) - Sense of Control (pre)	.5612244898	.4886134631	.0923392650	.3717599679	.7506890117	6.078	27	.000
Pair 3	Motivation (post) - Motivation (pre)	.2698412698	.5224091876	.0987260567	.0672721340	.4724104056	2.733	27	.011

Based on the results of both the *Wilcoxon signed-ranked test* and *t-test*, we can be confident that there was a change in empowerment outcomes of the farmers due to the use of MBIS.

6.3.2 Analysis Two: What is the relative change of empowerment outcome of each farmer because of MBIS?

The objective of analysis two was to understand the effect of a change in the environment such as technology intervention on individual behavior of the farmers. The change in individual behavior was looked at in the context of empowerment outcomes such as self-

efficacy, sense of control and motivation. Therefore, the relative change of each empowerment outcome of each farmer was calculated using Formula 1 below.

Formula 1: Relative change in empowerment outcome = *(mean value of post data – mean value of pre data)/(mean value of pre data)*

The results of applying the formula can be seen in Table 6-9 below.

Table 6-9 : Relative changes of empowerment outcomes of the farmers

FID (Farmer ID)	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%
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%

To represent and analyse above results of 28 farmers clearly, I have divided them in to two tables; Table 6-10 and Table 6-11 below. Table 6-10 shows the FID (farmer ID) and empowerment outcome values where the *relative change was all positive*. Table 6-11 on the other hand shows the FID and empowerment outcome values where there was *both positive and negative relative change.*

Table 6-10: All positive relative change of empowerment outcomes

FID	Sense of Control (%)	Motivation (%)	Self-Efficacy (%)
1	15%	13%	41%
2	31%	28%	63%
3	27%	2%	10%
4	22%	8%	35%
7	6%	16%	27%
8	11%	17%	17%
9	0%	2%	47%
11	21%	24%	9%
13	14%	14%	5%
14	8%	11%	19%
17	14%	10%	55%
21	3%	7%	24%
22	19%	2%	16%
25	5%	14%	97%
27	15%	0%	34%
28	9%	2%	78%

Table 6-11 : Both positive and negative relative changes of empowerment outcomes

FID	Sense of Control (%)	Motivation (%)	Self-Efficacy (%)
5	-5%	17%	20%
6	26%	-8%	9%
10	3%	-11%	6%
12	31%	-2%	43%
15	6%	-9%	7%
16	12%	-2%	20%
18	3%	7%	-2%
19	0%	-9%	19%
20	-5%	11%	46%
23	8%	-4%	22%
24	7%	-4%	4%
26	13%	-2%	29%

6.3.3 Analysis Three: Is there a significant relationship between empowerment outcomes?

In this analysis, the Bivariate Pearson Correlation was performed to determine whether there was any significant linear relationship among *pre* and *post* values of empowerment outcomes. The Bivariate Pearson Correlation produces a sample correlation coefficient, *r*, which measures the strength and direction of linear relationships between pairs of continuous variables (Statistics 2013).

Table 6-12 below shows the Bivariate correlation results for March 2015 data. *The empowerment outcomes showed no significant correlations.*

Table 6-12 : Bivariate Correlation Results (March 2015 data)

Correlations

		Self-Efficacy (pre)	Sense of Control (pre)	Motivation (pre)
Self-Efficacy (pre)	Pearson Correlation	1	.228	.085
	Sig. (1-tailed)		.122	.334
	N	28	28	28
Sense of Control (pre)	Pearson Correlation	.228	1	.032
	Sig. (1-tailed)	.122		.435
	N	28	28	28
Motivation (pre)	Pearson Correlation	.085	.032	1
	Sig. (1-tailed)	.334	.435	
	N	28	28	28

Next the Bivariate correlation analysis was performed on September 2015 data after farmers have used the MBIS during the farming season. The results showed a *significant correlation among the empowerment outcomes* (Table 6-13 below).

a) Self-efficacy (post) was *significantly correlated* with sense of control (post), r =.434, p (one-tailed) < .05
b) Self-efficacy (post) was *significantly correlated* with motivation (post), r =.326, p (one-tailed) < .05
c) Sense of control (post) was *significantly correlated* with motivation (post), r =.504, p (one-tailed) < .01,

Table 6-13 : Bivariate Correlation Results (Sept 2015 data)

Correlations

		Self-Efficacy (post)	Sense of Control (post)	Motivation (post)
Self-Efficacy (post)	Pearson Correlation	1	.434*	.326*
	Sig. (1-tailed)		.011	.045
	N	28	28	28
Sense of Control (post)	Pearson Correlation	.434*	1	.504**
	Sig. (1-tailed)	.011		.003
	N	28	28	28
Motivation (post)	Pearson Correlation	.326*	.504**	1
	Sig. (1-tailed)	.045	.003	
	N	28	28	28

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).

6.3.4 Analysis Four: Is the change due to MBIS?

In this analysis, self-efficacy data of November 2013 and March 2015 were compared to see whether the introduction of MBIS was the reason for the changes in the empowerment levels of farmers. As the MBIS was deployed in March 2015, it was not present in the environment 16 months prior to that.

Evaluating *Analysis four* data for normality

Table 6-14 : Skewness and Kurtosis z-values test

Statistics

		Self-efficacy (Nov 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 6-14 above shows that Skewness and Kurtosis z-values for self-efficacy values of Nov 2013 and March 2015 were normally distributed. Further Shapiro-Wilk normality

test showed a *p*-value above .05 for both self-efficacy (Nov 2013) and Self-Efficacy (March 2015). (see Table 6-15). Therefore, we concluded that the data was normally distributed.

Table 6-15 : 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 (Nov 2013)	.063	28	.200*	.982	28	.898

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

To compare the means of *Self-efficacy (Nov 2013)* and Self-Efficacy (March 2015) *dependent t-test* was performed (Table 6-16 below). Sig. (2-Tailed) value in this test was .156, which is greater than .05. Therefore, there was no statistically significant difference between Self-efficacy (Nov 2013) and Self-Efficacy (March 2015) data.

Table 6-16 : Dependent t-test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Dev	Std. Error Mean	95% confidence Interval of the difference				
				Lower	Upper			
Pair 1 SE(Nov 2013) – SE (Mar 2015)	1.18478	4.29150	.81102	-2.84885	.47929	-1.461	27	.156

Note: SE = Self-Efficacy

6.3.5 Analysis Five: Is there a relationship between usage of the application by the farmers and their empowerment levels?

In analysis four, I concentrated on the usage patterns of the application by the farmers and decided to investigate any relationships between usage and empowerment outcomes. Once a farmer logged on to the application, they can visit many areas in the application.

We selected several areas of the application help them make informed decisions. These activities are shown in Table 6-17 below.

Table 6-17: Names and descriptions of activities

Name of activity	Description of the activity
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

Whenever a farmer did an activity on the application, that action was logged on a server. Each log had the name of the farmer, date, time, name of the activity and any other data related to that activity as attributes. These logs were extracted from the server and the number of logs for each activity of each farmer was computed. From the logs, following computations were carried out.

The Total no. of all logged activities by each farmer was computed by counting the number of log entries for all activities.

Formula 2: *Total no. 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* were comprised of multiple activities. Selecting a crop to grow each season is one of major decisions that a farmer must make. Using the application, farmers

can carry out several activities in the application before making this final decision. The total number of logs for *selecting a crop process* was computed as follows;

Formula 3:

Total no. 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 also, farmers carry out several activities in the application. The total no of logs on *selling a product/service* was computed as follows;

Formula 4:

Total no. of logs on selling a product/service = My Offering Stage Selection + My Offering Addition + My Offering Deletion

The statistics of these logs are shown in Table 6-18 below.

Table 6-18 : 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
a. Multiple modes exist. The smallest value is shown.				

In section 6.1, the instruments that were used to measure the empowerment outcomes: *sense of control, motivation and self-efficacy,* were presented. This was done to investigate whether there was a *significant* relationship between the *results of empowerment outcomes and the logs of the activities of the application*. If usage correlated to

empowerment outcomes it would be evidence, suggesting that the application had influenced the outcome. Therefore, Bivariate Pearson Correlation was performed for empowerment outcomes (*post*) and the logs created using formulas 1, 2, 3 and 4. The results in Table 6-19 below showed a significant relationship between motivation (post) and the following logs.

a) motivation (post) was *significantly correlated* with logs of "login to the application" process, r = .342, n=28, p (one-tailed) < .05
b) motivation (post) was *significantly correlated* with logs of "total no of all activities", r = .389, n=28, p (one-tailed) < .05
c) self-efficacy (post) was *significantly correlated* with logs of "login to the application" process, r = .437, n=28, p (one-tailed) < .01
d) logs of "login to the application" process was *significantly correlated* with logs of "total no of all activities", r = .871, n=28, p (one-tailed) < .01

Table 6-19: Correlation between empowerment outcomes and logs

Correlations

		Sense of Control (post)	Motivation (post)	Self-Efficacy (post)	Logs of "login to the application" process	Logs of all activities
Sense of Control (post)	Pearson Correlation	1	.504**	.434*	.182	.175
	Sig. (1-tailed)		.003	.011	.177	.187
	N	28	28	28	28	28
Motivation (post)	Pearson Correlation	.504**	1	.326*	.342*	.389*
	Sig. (1-tailed)	.003		.045	.037	.020
	N	28	28	28	28	28
Self-Efficacy (post)	Pearson Correlation	.434*	.326*	1	.437**	.274
	Sig. (1-tailed)	.011	.045		.010	.079
	N	28	28	28	28	28
Logs of "login to the application" process	Pearson Correlation	.182	.342*	.437**	1	.871**
	Sig. (1-tailed)	.177	.037	.010		.000
	N	28	28	28	28	28
Logs of all activities	Pearson Correlation	.175	.389*	.274	.871**	1
	Sig. (1-tailed)	.187	.020	.079	.000	
	N	28	28	28	28	28

**. Correlation is significant at the 0.01 level (1-tailed).

*. Correlation is significant at the 0.05 level (1-tailed).

6.4 Discussion

In Sri Lanka there are two mobile-based applications designed for farmers to obtain agriculture market information; Dialog trade net (Dialog Sri Lanka 2010) and 6666 Agri-price index (HARTI 2014). Prior to deployment of MBIS in March 2015, no other mobile applications that featured empowerment processes which supported the livelihood

activities of farmers existed. Farmers received required information from scattered and disparate sources; agriculture officers, leaflets, booklets, family and friends, radio and television. In some instances, they received information late or in an incorrect format and context. The data collected in March 2015 (*pre data*) represented a situation where farmers did not use any technology or applications that had empowerment oriented processes. During the March – September 2015 farming season, farmers used the MBIS and, when data was collected in September 2015 (*post data*), it represented a situation where farmers had been using an artifact that was developed based on an empowerment framework. The artefact had empowerment oriented processes which assisted farmers to carry out their farming activities.

6.4.1 Relative change of empowerment outcomes of the farmers

The results of a *Wilcoxon signed-rank test* and *t-test* conducted on sense of control, motivation and self-efficacy showed a change from the *pre* to the *post* data (see section 0). The *t-test* results of the change of the empowerment outcomes showed a relative positive change of 11%, 6% and 25% for sense of control, motivation and self-efficacy respectively for the group. Figure 6-1 below shows the relative changes of empowerment outcomes for the individual farmers. It illustrates changes of intrinsic attributes of farmers and exhibits their different behaviour patterns.

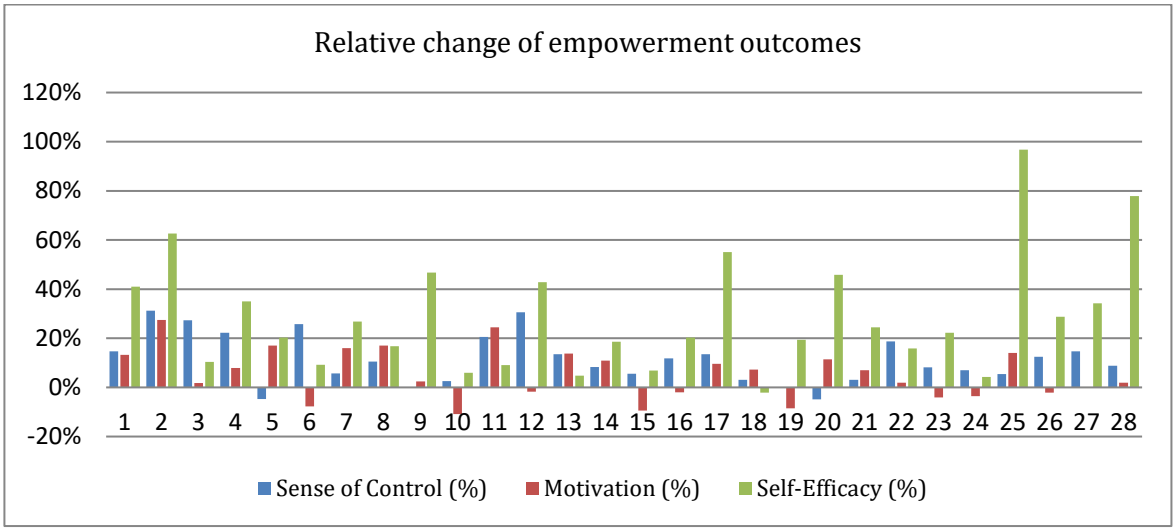

Figure 6-1 : Relative change of empowerment outcomes of the individual farmers

There is growing evidence that personal cognition influences the instigation, direction, and persistence of behaviours. Various theoretical traditions emphasise the importance of individuals' beliefs concerning their capabilities to exercise control over importance aspects of their lives (Bandura 1982; Corno and Mandinach 1983; Dweck and Leggett 1988; Schunk 1987; Stipek and Weisz 1981). A change of a person's intrinsic attributes can be due to many reasons, including personal, social and environmental factors. During the period of this investigation, one change that occurred in the farmers' environment was the introduction of the MBIS and this is likely to be one of the reasons for the improved empowerment outcomes.

6.4.2 Role of self-efficacy in behavioural change

The results of *analysis two* revealed the different behaviour patterns of farmers (see section 6.3.2). Self-efficacy was one of the three empowerment outcomes that was measured. Self-efficacy is a belief that makes a difference in how people think, feel and act and refers to "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura 1986).

In this investigation, self-efficacy data showed the highest positive relative change of 25%. People have varying levels of self-efficacy that they have derived from prior experience, personal qualities such as abilities and attitudes and social support (Schunk 1995). 96% of the farmers (except for FID 18) in the group had positive change in their self-efficacy outcome. As the MBIS was designed to assist their farming activities in a customised manner, farmers could use different choices and evaluate the impact of their choices on their final outcome. It seems therefore that the artefact has helped them make informed decisions after evaluating the options they have. This process has increased their belief that they can organise and execute actions that affect their livelihood.

It was observed that 57% of the farmers in the group (FID 1, 2, 3, 4, 7, 8, 9, 11, 13, 14, 17, 21, 22, 25, 27, 28) displayed a positive change in all three empowerment outcomes (see Table 6-10 above). 43% of the farmers displayed positive change in two empowerment outcomes and negative change mostly in *motivation* empowerment outcome (see Table 6-11 above). The artefact seems to have helped improve the self-efficacy level of the farmers (a positive relative change of 25%) but less so of motivation (only 6%). It is possible that, because the farmers chose to be in the study well before the artefact was introduced, that they were already motivated and so the relative change in their *motivation* during the *pre* and *post* data collection period was small. Since they now felt competent and with greater self-efficacy their motivation to change things was not so high, as essentially, they had achieved their goals in using the artefact.

According to (Gallagher 2012), self-efficacy beliefs do not necessarily reflect an individual's intention or motivation to pursue a particular goal. It is possible to feel extremely efficacious for a goal or task that one cares little about or to feel ineffective about extremely important goals. It is in the pursuit of the most valued goals, however,

that self-efficacy beliefs become the most important and have the most impact on eventual outcomes (Gallagher 2012).

6.4.3 Correlation among empowerment outcomes

The results of *analysis three* (see section 6.3.3) showed in the September 2015 data, a *significant correlation among empowerment outcomes*: self-efficacy, motivation and sense of control. Bandura's social cognitive theory can be used to describe these results. Social cognitive theory provides a model for understanding human emotion, behaviour, cognition, and motivation. It emphasises how humans actively interact with and help shape the environment (Bandura 1986). The theory suggests that each of the three areas: environment, behaviour of a person and his/her personal factors (such as cognitive or emotional/biological) interact with each other. Each of these areas is shaped by, and helps shape the other two. The relative influence of these factors is thought to vary according to the situation. Furthermore, the relative speed with they influence one another can also vary (Gallagher 2012).

During the March – September 2015 period, one change that happened in the environment was the presence of the MBIS. Farmers interacted with the environment through the MBIS to carry out their farming activities and this influenced change in their behaviour. The correlation between their empowerment outcomes signifies the change in their behaviour which in turn influenced a change in their personal attributes. Figure 6-1 above shows different positive and negative levels of these personal attributes of the farmers. They are different as individuals react differently and at different speeds to the changes in the environment.

Correlation between Self-efficacy and Motivation

Empowerment outcomes derived from September 2015 data collection revealed a significant correlation between self-efficacy and motivation ($r = .326$, $n=28$, $p<0.05$, Table 6-13). These results are consistent with the growing evidence that self-efficacy influences motivation (Cohen-Mansfield et al. 2003; Corno and Mandinach 1983; Pintrich and Schunk 2002; Schunk 1989). Self-efficacy beliefs received increasing attention in many studies in different domains and populations. Those studies confirmed the important relationship between the self-efficacy and the motivation. While the most cases reported in this context concerned learning in schools and tertiary education, the introduction of the MBIS to the farmers can also be considered as a learning experience for them.

Motivation and self-efficacy are enhanced when people perceive they are performing more skilfully or becoming more competent. Lack of success or slow progress will not necessarily lower self-efficacy and motivation if individuals believe they can perform better by adjusting their approach (Schunk 1989).

Sense of Control and its correlation to Self-efficacy and Motivation

Empowerment outcomes derived from September 2015 data collection showed a significant correlation between sense of control and self-efficacy ($r=.434$, $n=28$, $p<0.05$, Table 6-13) and sense of control and motivation ($r=.504$, $n=28$, $p<0.01$, Table 6-13).

One of the theories most often discussed in relation to self-efficacy is Julian Rotter's Locus of Control theory (Rotter 1966). Locus of control refers to people's very general, cross-situational beliefs about what determines the outcomes in their life. People can be classified along a continuum from very internal to very external. (Rotter 1990) describes internal locus of control as: the degree to which people

expect that reinforcement or an outcome of their behaviour is contingent on their own behaviour and personal characteristics. People's belief in their ability to change things may well make them more confident and so they will seek information to help them influence people and situations. They are also likely to become more motivated and success-oriented.

Similarly, in this study, it appears that farmers who used the MBIS believed that they can take actions which would lead to better outcomes. This was shown with a significant correlation between self-efficacy and sense of control (Table 6-13 above). Farmers were also motivated to take actions which would lead to better outcomes in the end. In this study, this was shown with a significant correlation between motivation and sense of control (Table 6-13 above).

6.4.4 Relationship between the usage of the application by the farmers and their empowerment outcomes

This section discusses the results of *analysis four* (see section 6.3.4). Table 6-18 above shows the statistics of the different logs that were recorded on the server of the application: logs of "login to the application process", logs of "all activities", logs of "selecting a crop process" and "logs of selling a crop" process (see Table 6-17 above for a description of the activities).

The statistics of these logs contained large standard deviations, therefore, median and mode values were computed to understand how farmers used the application. Large variances were found in the log data, perhaps because the statistics represent a cohort of farmers who have different levels of motivation, ability and self-belief to use technology. The intention to do or perform something starts with self-belief and motivation, and with regards to using the MBIS application, "login to application activity" indicates *intention*. It is the first entry point to the application and the first activity that a farmer must do.

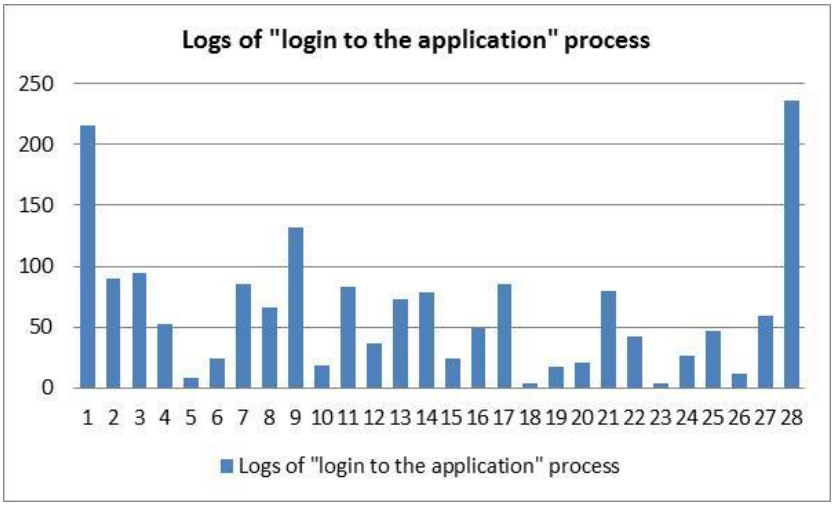

Figure 6-2: Logs of "log in to the application" process

Table 6-20 : Negative empowerment outcome

Farmer ID	Negative empowerment outcome
6, 10, 12, 15, 16, 19, 23, 24, 26	Motivation
5, 20	Sense of Control
18	Self-efficacy

To gain a better understanding, the data was further examined for specific activities performed by the farmers on the application. Figure 6-2 above shows the logs of the farmers in "log in to the application process". For this discussion, logs below the median value of 50.5 as low were considered (see Table 6-18). Farmers with FID 5, 6, 10, 12, 15, 16, 18, 19, 20, 22, 23, 24, 25 and 26 recorded logs below this median value. To investigate whether there is any relationship between these low logs and their empowerment outcomes, a comparison of these results with that of *analysis two* was performed (see section 6.3.2 for the details of Analysis Two). Table 6-21 below shows the farmer IDs in *analysis two* and *analysis four*.

Table 6-21 : Comparison of results of analysis two and analysis four

Analysis Four Farmer IDs that have logs *below the median value* (Figure 6-2)	5, 6, 10, 12, 15, 16, 18, 19, 20, **22**, 23, 24, **25**, 26
Analysis Two Farmers IDs that reported *negative empowerment outcome* (Table 6-11)	5, 6, 10, 12, 15, 16, 18, 19, 20 23, 24, 26

Table 6-21 shows that except for the farmers with FID 22 and 25, all the others, FID 5, 6, 10, 12, 15, 16, 18, 19, 20, 23, 24 and 26 who recorded a low log count in "log in to the application process", also recorded negative empowerment outcome. Farmers with FID 22 and 25 had recorded all positive empowerment outcomes (See Table 6-10 above). This comparison between empowerment outcomes and the logs of application use provides a coarse relationship between the two. It indicates that the level of self-belief, motivation and ability that a person has affects the behaviour of that person in different situations (Bandura 1986).

After a farmer has logged in and entered the application, they can either stop doing other activities or continue to navigate to other activities. To investigate what farmers did after they logged on to the application, an analysis of the logs of "login to the application process" and "all activities" was carried out. These results are shown in Figure 6-3 below.

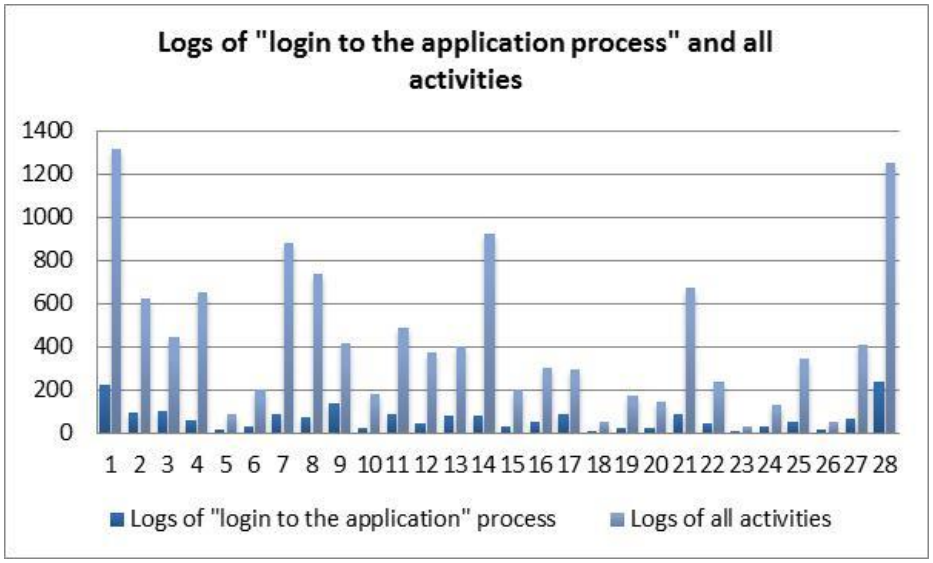

Figure 6-3 : Logs of "login to the application process" and all activities

The logs below the median value of 357, in logs of "all activities" were considered as low (see Table 6-18 above). Farmers with FID 5, 6, 10, 12, 15, 16, **17**, 18, 19, 20, **22**, 23 24 and 26, recorded logs below this median value. Except for the farmers with FID 17 and 22, all the other farmers recorded negative empowerment outcomes (see Table 6-9 above). These farmers did not do many activities in the application. After logging into the application, farmers who recorded positive empowerment outcomes visited other areas of the application.

Some of the farmers who had negative empowerment outcomes displayed a similar pattern in the logs of other activities. For example, when a farmer wants to select a crop to grow, they carry out several activities to make an informed decision. Figure 6-4 below shows logs of different activities that a farmer did when "selecting a crop to grow" process. It shows that farmers who recorded negative empowerment outcomes; with FID 5, 6, 10, 15, 18, 19, 20, 23, 24, and 26 showed low logs in "selecting a crop to grow" process (see Table 6-9 above). Other farmers with positive empowerment outcomes recorded high logs.

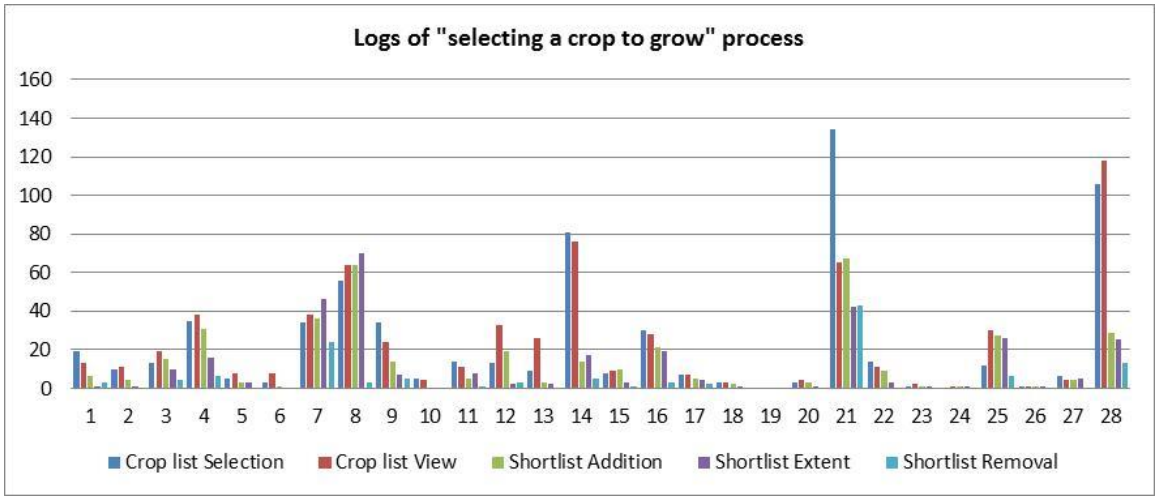

Figure 6-4: Logs of "selecting a crop to grow" process

Figure 6-5 below shows more activities of the application. For example, farmers can calculate the expense of a possible cultivation before deciding on which crop to grow. In addition to the cost calculation, farmers have access to a price list and contact details of various suppliers through the application. This assists them in their expense calculation process. Once a farmer has finished the expense calculation process, they can save the details of for future references.

Another activity a farmer can do in this application is save their personal information in My Information activity. When necessary, a farmer can edit this information too.

Some people believe that the outcome of an event is the result of their own behaviour and effort. They also believe that they have the ability to change things (Rotter 1990). Compared with persons who doubt their capabilities, those with high self-efficacy for accomplishing a task participate more readily, work harder, persist longer when they encounter difficulties, and achieve at a higher level. (Schunk 1995). As shown above, the analysis of the logs of the application supports these established theories.

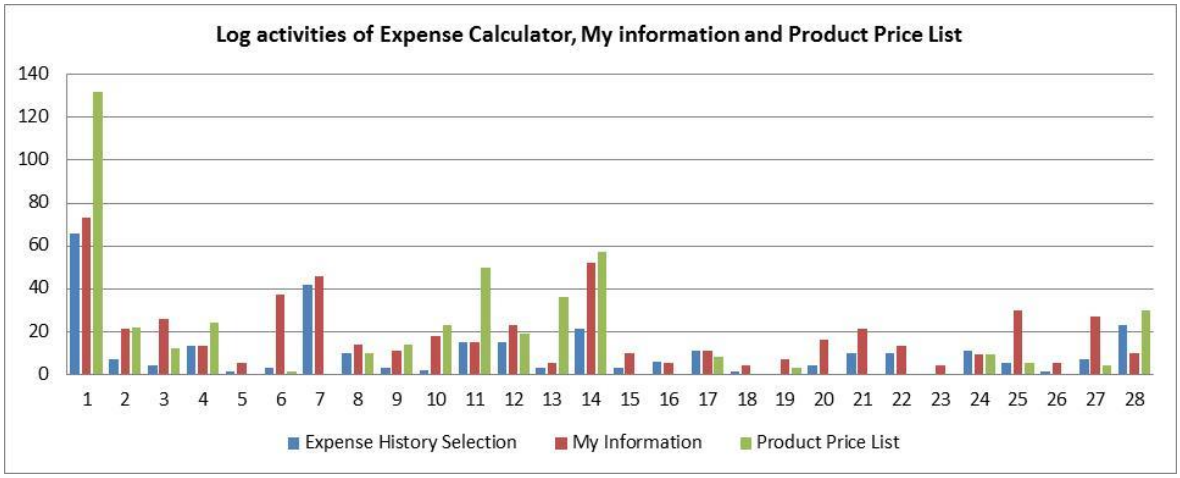

Figure 6-5 : Log activities of Expense Calculator, My Information and Product Price List

6.4.5 Correlation between empowerment outcomes and the logs

Results of *analysis four* (See Section 6.3.4 above) showed *significant correlations* between empowerment outcomes and logs. Self-belief and motivation drives a person to take an action (Pinder 1998, p11; Rotter 1990). In this study, the action that a farmer had to take was to use the application to carry out activities that can 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 *(*see Table 6-19). After logging to the application, a highly motivated farmer may explore other areas of the application to do more activities. This is shown 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.

motivation (post) was *significantly correlated* with logs of "login to the application" process, $r = .342$, $n=28$, p (one-tailed) $< .05$

motivation (post) was *significantly correlated* with logs of "all activities", $r = .389$, $n=28$, p (one-tailed) $< .05$

6.4.6 Was the change in empowerment outcome because of introduction of MBIS?

Often, the environment we live in introduces new ideas and support. For example, in the case of farmers, it could be a new TV program on agriculture or a subsidised fertiliser program. People may feel motivated and empowered because of many things that are happening in the environment. It is difficult to pin point exactly which helped to achieve that.

In order to confirm the positive changes observed in empowerment outcomes, discussed in sections 6.4.1, 6.4.2, 6.4.3, 6.4.4 and 6.4.5, was a result of introducing MBIS, a comparison of self-efficacy values of November 2013 and March 2015 was made. As the MBIS was deployed in only March 2015, it was not present in the environment 16 months prior to that. When paired *t-test* was performed on Self-efficacy data of November 2013 and March 2015, it returned a Sig (2-Tailed) value of .156 which is greater than .05. This indicated that there was no statistically difference between November 2013 and March 2015 self-efficacy data when the MBIS was not present in the environment. Further, if there was a new TV program or a subsidised fertiliser program in the environment, it did not affect self-efficacy levels of farmers.

When paired t-test was performed on Self-efficacy data of March 2015 and September 2015, it returned a Sig (2-Tailed) value less than .05, indicating there was a statistically difference between two sets of data. As the MBIS was present during this period, we can conclude that this change in empowerment outcomes of farmers was due to the introduction of the MBIS. Only self-efficacy data was chosen for this purpose. However, if the values of other empowerment outcomes such as sense of control and motivation were also used, we would have seen a similar result during November 2013 and March 2015 period because of the relationships between empowerment outcomes.

6.5 Relating results to the MBIS design

This study designed and implemented an empowerment framework on which a MBIS was developed to empower farmers. The details of the empowerment framework and how the MBIS was implemented based on this framework was discussed in chapter 5.

Power and choice represent two fundamental forces that govern human behaviour. Power has been conceptualised as an interpersonal construct which affects an individual's decision making (Anderson and Galinsky 2006) and ability to take actions (Galinsky et al. 2003). Choice has largely been treated as an intrapersonal construct that concerns the ability to select a preferred course of action (Averill 1973). Both power and choice satisfy a need for personal control, the belief that events are influenced by and contingent upon one's own behaviour and not fate, circumstances, other people, or uncontrollable physical forces (Rotter 1966).

Decades of psychological research have shown that providing choice will increase an individual's sense of personal control (Rotter 1966; Taylor and Brown 1988), feelings of intrinsic motivation (Deci 1981; Deci and Ryan 1985) and greater persistence, better performance, and higher satisfaction (Langer and Rodin 1976; Zuckerman et al. 1978).

When extending the above theory to the design process, detailed attention was given to implementing choices in the empowerment processes. Following were the choices provided.

a) Which farm to use for the season
b) Which crop to grow
c) Which fertilizer to use
d) Which pesticide to use
e) Which chemical to use
f) How much to use in (c), (d) and (e), i.e. the recommended amount given by the artifact or personal judgement
g) Which supplier to buy from
h) Whether to do a cost-benefit analysis prior to decision in (b)
i) Whether to save the cost-benefit analysis for future expense comparisons

j) Whether to compare the expense of a previous session before deciding in (b)
k) Whether to use the artifact to advertise and sell one's own products to the farming community

The details of how above choices were designed in the artifact are provided in section 5.4.4.

6.6 Summary

The aim of this chapter was to evaluate the effectiveness of the empowerment framework on which the MBIS is implemented. When the effectiveness of the empowerment framework was considered, the chapter tried to establish whether the MBIS has helped farmers improve their empowerment levels. This aim was carried out in several stages. To measure empowerment outcomes, several relevant instruments based on the published literature was developed. The MBIS was then deployed with Sri Lankan farmers at the beginning of a farming season. The same questionnaire was used with the same group of farmers to gather farmers' level of empowerment at *pre* and *post* deployment of the MBIS. The gap between the two data collections was 6 months.

The analysis of data showed that there was a relative positive change of empowerment levels for most farmers because of them using the MBIS during the selected farming season. The results also showed some significant correlations between empowerment outcomes. This supported the established theory on relationships of empowerment outcomes. An analysis of usage of MBIS by farmers was conducted by analysing the usage logs of various activities done with the application. These results showed a significant relationship between how farmers used the application and their behaviour depending on their levels of motivation, self-belief and ability. It can be concluded that the empowerment framework was effective. The artefact, the MBIS, that was implemented based on an empowerment framework, can be used to empower farmers in their livelihood activities.

7 Conclusions

In chapter 1, the research aim of this thesis was specified and research problem was identified. This chapter presents how this research project fulfilled the aim and provides a conclusion as a summary of major outcomes. It also presents the contribution made to the research community, the progress of the overall project and the impact it had made in Sri Lanka. It is followed by an overall reflection, suggestions for future research, and finishes with a brief discussion of opportunities and limitations of the research project.

7.1 Conclusions – Major outcomes of the thesis

As stated in Chapter 1, the main aim of this research was to *develop and validate an empowerment framework for developing mobile-based applications to empower users in their livelihood activities*.

The three major goals of the research were to:

1. Analyse, design and implement an empowerment framework
2. Analyse, design and implement a Mobile-based Information System based on the empowerment framework
3. Evaluate the effectiveness of the empowerment framework on which the Mobile-based Information System was developed as to establish whether the artefact has helped farmers to improve their empowerment levels.

To achieve the first goal, an initial empowerment model was created from the psychology literature. This model was evaluated and revised in the context of empowering Sri Lankan farmers to improve their livelihood. With the colleagues of the collaborative research group, this research carried out two field trials to understand how farmers work, what information they need for their work, how they receive information and make decisions at crucial stages of a farming cycle, the problems and issues they face, and their

meaningful goals and outcomes. From these insights, I developed an empowerment framework.

When working towards the second goal, a Mobile-based Information System (MBIS) based on this framework was developed. The contribution of *this thesis* in the development process was to create empowerment processes embedded with choices to assist farmers achieving their meaningful goals. The design took into consideration choices which were relevant and useful. The objective was to enable farmers to identify, choose and select their choices and then to evaluate the impact of their choices on the outcome. The implementation of choices was enhanced with different types of customised knowledge to support a more meaningful and informed decision-making process. This was followed by designing mobile interfaces for easy navigation through the application.

The final goal was to evaluate the effectiveness of the empowerment framework on which the MBIS was developed, to ascertain whether it affected the empowerment levels of the farmers. For this purpose, two further field trials were carried out, in March 2015 and September 2015, to capture *before* and *after* data. In March 2015, at the beginning of a farming cycle, the MBIS was deployed and the farmers were provided with smart mobile phones to access it during their farming session. At the end of the farming session in September 2015, farmers met the researchers again. In these two field trials, a questionnaire was designed to measure the empowerment outcomes, to gather data at the beginning and end of the farming cycle. This data was analysed to determine the impact of MBIS on the empowerment outcomes of the farmers during the farming cycle.

Several analyses were carried out to determine the impact of the MBIS on the empowerment levels of farmers. The analysis showed that there was a relative positive change of empowerment levels for most farmers because of using the MBIS; *25% in self-efficacy, 11% in sense of control and 6% in motivation*. These results also showed some

significant correlations between the empowerment outcomes of farmers thus supporting the established theory on the relationships of the empowerment outcomes. An analysis of the usage of the MBIS by analysing usage logs of various activities they carried out on the application was also conducted. These results showed that there was a significant correlation between how farmers used the application and behaviour which is dependent on motivation, self-belief and ability. From above results, it could be concluded that the goals of the research were achieved successfully.

This research used Design Science Research methodology. Table 7-1 shows how the research was guided by the guidelines of this methodology.

Table 7-1 : Design Science Research Guidelines

Design Science Research Guidelines	
Guideline	Description
Guideline 1: Design as an Artefact	The following artefacts were created. a) Enhanced empowerment model for Sri Lankan farmers b) Interaction flow models for empowerment processes c) An Empowerment framework to create mobile-based artefacts d) Instruments to measure empowerment outcomes
Guideline 2: Problem Relevance	The overall objective was to solve an agriculture production problem in Sri Lanka. The objective of *this research* was to investigate how to implement a technology-based solution to empower users who are in desperate situations to take actions and improve their lives.
Guideline 3: Design Evaluation	Design evaluation was an iterative and incremental process. From feedback received from one evaluation, design was enhanced. The following design evaluations were carried out to achieve a final design of the empowerment framework. a) Evaluation of the profit calculator to investigate how technology can be used to empower farmers b) Paper-prototype evaluation of Expense Calculator to assess usability c) Evaluation of the Empowerment Framework to assess the impact of the MBIS on the empowerment outcomes of farmers.
Guideline 4: Research Contributions	The following were the research contributions.

	a) An empowerment model for Sri Lankan farmers with clearly identified goals, empowerment processes, outcomes and tools to support b) Methodology for design for empowerment c) An empowerment framework on which mobile-based artefacts can be built d) Instruments to measure empowerment outcomes and analytical methods to measure the outcomes
Guideline 5: Research Rigor	Rigor in this research was derived from the theoretical foundations of empowerment theory, psychology literature and technology development.
Guideline 6: Design as a Search Process	It was an iterative process of many relevance, design and rigor cycles. To understand the problem clearly, we conducted two field trials with the farmers. From the insights that were gained and the related literature, the design of the artefact was enhanced. Another two field trials were conducted during the evaluation process.
Guideline 7: Communication of Research	The new findings of the research were communicated via the following publications. 1. Ginige, T. and Ginige, A. (2011, December). *Towards Next Generation Mobile Applications for MOPS: Investigating emerging patterns to derive future requirements*. Presented at the 12th International Conference on Advances in ICT for Emerging Regions, Colombo, Sri Lanka. 2. Giovanni, P. D., Romano, M., Sebillo, M., Tortora, J., Vitiello, G., De Silva, L., Goonethilaka, J., Wikramanayake, G., Ginige, T., and Ginige, A. (2012, September). *Building Social Life Networks through Mobile Interfaces: A Case Study of Sri Lankan Farmers*. Presented at the 9th Conference of the Italian Chapter of AIS, Rome, Italy. 3. Ginige, A., Ginige, T., and Richards, D. (2012, June). *Architecture for Social Life Network to Empower People at the Middle of the Pyramid*. Paper presented at the 4th International United Information Systems Conference, Yalta, Ukraine. 4. Ginige, T and Richards, D. (2012, December). *A Model for Enhancing Empowerment in Farmers using Mobile Based Information System*. Paper presented at the 23rd Australasian Conference on Information Systems (ACIS 2012), Geelong, Australia. 5. Giovanni, P. D., Romano, M., Sebillo, M., Tortora, G., G., Vitiello., De Silva, L., Goonethillake, J., Wickramanayake, G., Ginige, T., and Ginige, A. (2012, June). *User Centered*

Scenario Based Approach for Developing Mobile Interfaces for Social Life Networks. Paper presented at the 34th International Conference on Software Engineering Zurich, Switzerland.

6. Ginige, T and Richards, D. (2013, December). *Development of mobile-based empowerment processes for Sri Lankan framers.* Presented at the 24th Australasian Conference on Information Systems, Melbourne, Australia.

7. Ginige, A., De Silva, LNC., Ginige, T., Giovanni, P.D., Walisadeera, A.I., Mathai, M., Goonetillake, J., Wikramanayake, G., Vitiello, G., Sebillo, M., Tortora, G., Richards, D., and Jain, R. (2014, September). *Towards an Agriculture Knowledge Ecosystem: A Social Life Network for Farmers in Sri Lanka*. Paper presented at the 9th Conference of the Asian Federation for Information Technology in Agriculture, Perth, Australia.

8. Ginige, T., Richards, D., and Hitchens, M. (2014, December). *Cultivation Planning Application to enhance Decision Making among Sri Lankan Farmers*. Paper presented at the Pacific Rim Knowledge Acquisition Workshop, Gold Coast, Australia.

9. Silva, L. D., Goonetillake, J., Wikramanayake, G., Ginige, A., Ginige, T., Giovanni, P. D., Walisadeera, A. I., Mathai, M., Vitiello, G., Sebillo, M., and Tortora, G. (2014, August). *Design Science Research Based Blended Approach for Usability Driven Requirements Gathering and Application Development*. Paper presented at the 2nd International Workshop on Usability and Accessibility focused Requirements Engineering, Karlskrona, Sweden.

10. Ginige, T and Richards, D. (2015, August). *Measuring Empowerment to evaluate the impact of a Mobile Based Information System for Sri Lankan farmers*. Paper presented at the 21st Americas Conference on Information Systems, Puerto Rico.

11. Silva, L. D., Ginige, T., Giovanni, P. D., Mathai, M., Goonetillake, J., Wikramanayake, G., Sebillo, M., Vitiello, G., Tortora, G., Tucci, M., and Ginige, A. (2016). Interplay of Requirements Engineering and Human Computer Interaction Approaches in the Evolution of a Mobile Agriculture Information System. In A. Ebert, S.R.

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7.2 Contribution of this research to the wider research community

The major contribution of this research is the implementation of the empowerment framework on which an artifact can be implemented to empower users. The framework has been implemented in prior work on identifying the core elements of the empowerment process, in describing the process as iterative, and by incorporating the both individual and social aspects of the construct.

As identified in section 1.3, current mobile-based solutions do not explicitly address empowerment. *This research* has closed that gap in knowledge by creating an artifact with empowerment processes based on empowerment theory. While there is a large body of knowledge on empowerment, these studies have not identified all the elements of the process or the links among them (Cattaneo and Chapman 2010). To address this, an empowerment framework was developed with a set of guidelines to support creation of an empowerment-oriented artifact (see section 5.1). One of the guidelines implemented is to identify an empowerment model with meaningful goals, empowerment processes that achieve these goals and outcomes, and linking these elements to support an iterative nature of the empowerment process.

Empowerment is an iterative process of action and reflection. The research applied this important *action-reflection* process at a higher level of the design of the MBIS. The rest of the guidelines in the empowerment framework specify what components are required for an *everyday process* to become an empowerment-oriented one. For example, to achieve meaningful goals, it is important to make informed decisions. To support this, the empowerment processes were designed with useful, motivating choices to support different behaviors of the farmers. To activate these choices, the empowerment processes were provided with different types of customized knowledge. Choices provide farmers an opportunity to take an action, reflect on the outcome and decide on whether to decide on that choice or select an alternative.

The impact element of the empowerment process involves an assessment of what happens following individual actions. The objective of this research was to measure impact on the individual levels of empowerment due to the MBIS. As described in Chapter 6, the evaluation of the effectiveness of the framework demonstrated that it can be used to empower the farmers in their livelihood activities.

The design of the empowerment framework comprises 3 related components. Table 7-2 below provides a summary of each component and indicates the research question it solved.

Table 7-2 : A summary of the main artifact, its constituent artifacts and contribution to the knowledge-base

Research Question	Investigative Questions	Method/technique used in DSR sub-cycle	Major Findings/Constituent Artefact	Contribution to knowledge-base		
				Extension or Addition	New	Publication (see Table 7-1)
RQ1: How can farmers be empowered in their livelihood activities?	RQ1.1 What are the goals of farmers and the opportunities and obstacles they have to achieve these goals?	Relevance -understanding the problem (1) Scenario-based approach	A list of goals of Sri Lankan farmers. a) To have financial security and feel safe. b) To have easy access to relevant and up-to-date information to make informed decisions c) To learn new skills and ideas d) To become an active member in the farming community	✔		[9]
	RQ1.2 What is a suitable working definition of empowerment in the context of Sri Lankan farmers?	Rigor – Learning (1) Related literature review	A working definition of empowerment for the Sri Lankan farmers. (see section 4.2) *Empowerment is an iterative process in which a person who lacks power individually and in social relationships, sets a personally meaningful goal oriented toward increasing power, takes action toward 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 (Cattaneo and Chapman 2010)			
	RQ 1.3 What is an initial conceptual empowerment model for Sri Lankan farmers?	Design – heuristic search (1) Exploration of possible designs and identifying a suitable one	An (initial) conceptual model of empowerment model (Figure 4-1)		✔	**[9]**
	RQ 1.4 How can technology be used to empower farmers: stage 1 – Initial investigation?	Rigor – Learning (2) Causal Analysis Design – Heuristic Search (2) Exploration of possible designs and identifying a suitable one Design – Functional Validation (1) Testing and correcting errors of the design Relevance – suitability validation (1) Questionnaire, Field trial	Profit Calculator tool to calculate profit/loss of farming expenses (Figure 4-2)		✔	**[5, 12]** [10]
	RQ 1.5 How can technology be used to empower farmers: Stage 2 – Enhancing profit calculator?	Relevance – Understanding the problem (2) Related literature review	Expense Calculator tool to plan the expenses of each stage of a farming cycle (Figure 4-2)		✔	

	RQ 1.6 How do farmers make decisions?	Relevance -understanding the problem (3) Questionnaire, Field trial	Farmers use information which is not-up-to-date, or not relevant or not complete to make their decisions which sometimes leads to unsatisfactory outcomes. To make meaningful decisions, different types of knowledge such as factual, procedural and aggregated are required.		✔	[8]

Research Question	**Investigative Questions**	**Method/technique used in DSR sub-cycle**	**Major findings/Constituent Artefact**	**Contribution to knowledge-base**		
				Extension or Addition	**New**	**Publication (see Table 7-1)**
RQ2: How to design a suitable mobile artifact to empower farmers?	RQ2.1 What are the elements of an empowerment framework? a) What are the empowerment processes? b) How to enhance decision making in the empowerment processes? What are the different types of knowledge required to	Rigor – Learning (3) Related literature review Design – Heuristic search (3) Exploration of possible designs and identifying a suitable one	An empowerment framework consists of the following guidelines: (see section 5.1). a) Identify and list meaningful goals. b) Identify and list empowering processes. c) Based on (a) and (b), design an empowerment model with meaningful goals, processes and empowerment outcomes. d) Identify and list useful and motivating choices in the context of the processes.		✔	[6]

	support decision making?		e) Identify and list different type of relevant, up-to-date knowledge required. f) Based on (d) and (e), design a mechanism to provide customized knowledge.			
	RQ2.2 What is an enhanced empowerment model for Sri Lankan farmers?	Design – Heuristic search (4) Exploration of possible designs and identifying a suitable one	An enhanced empowerment model consists of meaningful goals, empowerment processes (with supporting processes) and empowerment outcomes. <u>Meaningful goals</u>: (see section 5.1.1) e) Financial security and feeling safe. f) Easy access to relevant and up-to-date information with which to make informed decisions. g) Learn new skills and ideas. h) Active member in the farming community <u>Empowerment processes:</u> (see section 5.1.3) d) Finding crops to grow. e) Calculating Expenses. f) Selling products and services of farmers. <u>Supporting processes:</u> (see section 5.1.3) d) Viewing past expenses.		✔	[8, 11]

			e) Communication. f) Organizing finances. <u>Empowerment Outcomes:</u> (see section 5.1) a) Sense of control. b) Motivation. c) Self-Efficacy. d) Competence.			
	RQ2.3 How to implement choice in empowerment processes?	Rigor – Learning (4) Related literature review Design – Heuristic search (5) Exploration of possible designs and identifying a suitable one	The, *choice* was embedded in designing the empowering processes of the MBIS to support different behaviours of farmers, such as for farmers to identify and engage in choice processes, learn and develop new skills, reshape the set of given choices to be personally feasible within their specific situation, evaluate all the choices available and make decisions. (see section 5.3)		✔	
	RQ2.4 – How to design the MBIS to empower farmers?	Design – Heuristic search (6) Exploration of possible designs and identifying a suitable one	A detailed design of the MBIS consists of the following (see section 5.4). a) High level architecture of the MBIS. b) Design details of general functions of the mobile front; Register and Login. c) Design details of empowerment-oriented functions of the mobile front; Crop		✔	**[7, 9]** [1, 2, 4, 6]

			Selection, Expense Calculator, Expense History, My Offering. d) Role of the back-end data management (Commercial Supplier Database, Farmer Profile database, Production database), Agriculture Ontology and Geographical Information System (GIS). e) DFD diagram of MBIS to show the data flow among various functions of the MBIS. f) Design details for implementing choice and providing knowledge in empowerment-oriented processes. g) Mobile user interfaces of the MBIS.			

Research Question	Investigative Questions	Method/technique used in DSR sub-cycle	Major findings/Constituent Artefact	Contribution to knowledge-base		
				Extension or Addition	New	Publication (see Table 7-1)
RQ3: How to measure the effectiveness of the MBIS in relation to the empowerment	RQ3.1 What are suitable instruments to evaluate empowerment?	Rigor – Learning (5) Related literature review Design – Heuristic search (7) Exploration of possible designs and identifying a suitable one	A questionnaire was designed to measure empowerment outcomes such as sense of control, motivation and self-efficacy, of each farmer, without the use of the MBIS (pre-data) and after the use of the MBIS (post data). The questionnaire contained 7 questions on sense of control, 9 questions on motivation and 22 questions on self-efficacy. (see section 6.1)		✔	[3]
	RQ3.2 How to analyse the responses of the farmers, pre and post MBIS?	Rigor – Learning (6) Related literature review Relevance – Suitability validation (2) Questionnaire, Field trial (Part 1 – deployment and data gathering prior to MBIS, Part 2 – data gathering after MBIS)	The following statistical analysis methods were used. (see section 6.3) a) Skewness and Kurtosis z-values, the Shapiro-Wilk test p-value and Histograms, Normal Q-Q plots and Box plot to evaluate the normality of data. b) The dependent T-Test to compare the means of *pre* and *post* values of sense of control, motivation and self-efficacy. c) Relative change of empowerment	✔		

			outcomes of each farmer. d) Bivariate Pearson Correlation to determine whether there was any significant linear relationship among *pre* and *post* values of empowerment outcomes. e) Use of the logs of farmer activities to investigate any relationship between the usage of the MBIS by farmers and their empowerment level.			

Note: Ms Ginige's publications where she is the first author is shown in red colour in publications column.

7.3 Collective contribution to overall project goals

As mentioned in Chapter 1, *this research* was part of a collaborative research project to develop a Mobile Based Information System for farmers in Sri Lanka and to explore ways to overcome production problems for vegetables (see section 1.5). To address this complex problem, five higher degree students (4 PhDs and 1 Master) from Sri Lanka, Australia and Italy investigated various areas of the research problem. The outcomes of each areas of the investigation had an impact on the success of the overall project.

One of the issues of the agriculture domain in Sri Lanka is the inefficient flow of information among stakeholders. The current information models did not recognise which information or its form, were required by a stakeholder. Further, some stakeholders were not included in the information flow at all. This resulted in stakeholders making decisions in isolation and often led to an under-supply or over-supply market with high price variations. To address this issue, an Agriculture Information Eco System (PhD 1 in Sri Lanka) was developed. It identified all the stakeholders involved in the agriculture domain. Using aggregation and disaggregation techniques, the information needed by stakeholders, were mapped to the information generated by others to encourage information sharing and to reap the benefits of using current and relevant information in decision making.

Another issue that farmers faced was not being able to access relevant, up-to-date and timely information in a suitable format to make informed decisions. To fully utilise the benefits of an efficient information flow model with all its stakeholders, useful and actionable information should flow through it. Therefore, to address this issue, a user-centred, agricultural knowledge repository was built (PhD 2 in Sri Lanka). The online knowledge-base with a SPARQL endpoint was created to share and reuse the domain knowledge that can be queried based on user context.

Another one of the main objectives of the overall project was to provide relevant knowledge which is also customised to farmers to achieve their goals. For this purpose, a farmer context model was developed with which to identify factors specific to the farming domain - (Master degree in Australia). The main set of parameters used in the farmer context model geo-location mapped to the agro-logical zones and related attributes such as climate conditions, soil and elevation. The agro-logical zone attribute was used to query the Agriculture Ontology and provide specific information needed by the farmer.

Usability requirements play a major role when developing mobile based information systems. One of the aspects that was investigated in the overall project was elicitation of requirements and the design of usable mobile user interfaces (PhD 3 in Italy). In this research, a methodology was developed to support user interface design of mobile solutions.

The value of the individual projects was fully realised by implementing the MBIS based on the empowerment framework. None of the other PhD or Master projects investigated empowerment but instead relied on the empowerment framework developed in this thesis to bring the essential pieces they provided together. Therefore, to develop an artefact based on the empowerment framework to empower farmers, it was important to have:

a) An efficient information flow model that included all the stakeholders in the domain. To reap the benefits of informed decision making, it was important for stakeholders to identify their information needs and share information among them.
b) A User-Centred Agriculture Ontology that has relevant domain knowledge in a suitable format. This online knowledge-base was used to share and reuse the domain knowledge and provide timely information for farmers' queries.

c) Customised information for farmers created by capturing temporal, spatial and profile attributes from the sensory devices of a farmer's mobile phone.
d) A suitable mobile information system user interface with efficient usability requirements.

7.3.1 Impact of the MBIS for agriculture in Sri Lanka

The overall objective of finding a technology solution to solve an agriculture production problem in Sri Lanka was achieved. Because of this success, the collaborative research team submitted a proposal to the Sri Lankan Government in September 2015 to use the application to gain the food security in the country. The Sri Lankan Government has embraced this conceptual possibility and has announced a national project called "Govi Nena - Agriculture Intelligence". It will be a closed loop monitoring system for achieving sustainable agriculture production and was announced in the National Budget speech in November 2015 (Finance Minister 2015). It is the first time the idea of a closed loop system to achieve food security and stable and sustainable prices for farmers and consumers has been supported on a national level in Sri Lanka.

This success has made an impact in other areas and opened new opportunities.

a) In June 2015, Agro chemical companies in Sri Lanka started providing prices of agriculture inputs to MBIS.
b) In Nov 2015, the Sri Lankan government announced phase 2 of the overall project in the National budget to achieve food security in the country.
c) In Jan 2016, major buyers and supermarkets signed up to buy harvest from farmers.

7.4 Overall reflection and deeper impact

We currently live in an era where there is an explosive growth of data due to the technical advances in storage capacity, speed and the mobile technology. This data is continuously

collected, networked and analysed. Data is growing faster than ever before and by the year 2020, about 1.7 megabytes of new information will be created every second for every human being on the planet (Marr 2015). To manage the massive volumes of unstructured text, audio and video formats, there is a need to develop appropriate and efficient analytical methods, and relevant applications (Grandomi and Haider 2015; Jin et al. 2015). However, this is a complex process and even for the techno-savvy users in developed countries, this growth can be very overwhelming (Jin et al. 2015). Many applications are loaded with too much data. Users living in developing countries who may not have relevant technical skills or the knowledge may find it difficult to manage and utilise the large volumes of data they receive via their mobile devices. The volume of data might not necessarily motivate users to use applications. Most people who live in developing countries struggle in a cycle of poverty. Applications therefore should be developed for those in desperate situations to give them hope, provide them an opportunity to learn new ideas and skills and motivate them to take actions to change their situations.

When working on this project, the research team was fortunate to work with the same group of 30-50 farmers over 4 years. Like many farmers in the world, these farmers are also trapped in a poverty cycle. They became equal partners of our research group in trying to find a solution to the over production problems they were facing. The sense of equal partnership motivated them to participate in all the field trials. They were often faced with challenges associated with the unexpected weather, pests, diseases and changes in government policy. However, they always had hope that the outcome of the next season would be better. When working closely with them, it became clear how important it is to develop applications that empower people like Sri Lankan farmers. The applications should be designed with empowering processes built in so to meet the goals of the users, with choices to support different behaviours, to identify and engage in different activities, learn and develop new skills, reshape a set of given choices to be

personally feasible within specific situations and to evaluate all the choices available and make decisions. The process helps them make informed decisions. Though using a new technology such as a smart phone may be difficult for these users at beginning, understanding of what the applications can provide them, seeing the close connection between processes in the application and what they can do, and realisation of how it might help them to solve some issues, can motivate them to use the new technology.

In the context of Sri Lankan farmers who live in rural villages, they do not have the power, or even knowledge to influence the government authorities or other organisations to address the issues that affect their livelihood activities. As a community, Sri Lankan farmers are stronger and help each other when they face common problems and constant hardship. The real power that Sri Lankan farmers have is the social relationships that they have created in their culture. If these relationships are further enhanced with applications designed with their empowerment in mind and which can provide knowledge, self-efficacy and personal/community goal orientation, then the concept of empowerment becomes truly meaningful.

7.5 Future research directions

The empowerment framework presented in this thesis has a generic structure that guides to develop applications to empower users at individual level. The empowerment framework clearly defines the elements that an empowerment-oriented application should have. A different researcher may use different techniques than the ones reported in this thesis to investigate the elements in the empowerment framework. The generic nature of the empowerment framework assists to develop applications in different domains, communities, populations, and countries.

The empowerment framework designed in this thesis is based on the psychological empowerment which is a construct that incorporates the person's perceptions and

actions within their social context (Zimmerman 1990). It can be extended to understand and develop the processes involved in community empowerment which is gradually maximised as people progress from individual to collective action. Community empowerment is most consistently viewed in the literature as a process in the form of a dynamic continuum, involving personal empowerment, the development of small mutual groups, community organisations, partnerships and social and political actions (Jackson et al. 1989; Zimmerman 1988). Empowerment is a multi-level analysis that can span across different domains, populations, communities, populations, and countries (Zimmerman 1990).

Because of the generic nature of the empowerment framework presented in this thesis, it can be used to carry out further research in many dimensions. For example, different tools can be built on to the MBIS based on the framework to enhance the application. In addition, different levels of empowerment analysis such as community, domain, populations and country can be applied to the empowerment framework to determine their influence on the elements and validity of the empowerment framework.

7.5.1 Future developments to MBIS based on the empowerment framework

The following are possible future developments to enhance the MBIS.

Micro-finance: This is an important feature that can be developed based on the empowerment framework to empower farmers to achieve their goals. The agricultural micro-finance facility that concentrates on financial services for poor farm households and farm-related businesses. Providing financial services for the agriculture sector has been a challenge for many decades due to its high costs and high risks. Farmers with low incomes find it difficult to qualify for bank loans or credit. It is also the feeling that farmers are not creditworthy to have access to a bank loan. Considerable success has been achieved by some microfinance

institutions (MFIs) in providing sustainable microfinance services that contribute to resolving the agriculture credit problem by serving some of the rural poor. Yet there are significant obstacles for development of financial services that are accessible and adapted to a population which is poor in monetary forms, whose survival is dependent on exogenous factors such as climate, crop disease, or price movements. Often farmers need only a small amount of money in a hurry to buy the pesticide or a chemical to handle an unexpected situation caused by a new disease or a pest. As the farmers do not have quick access to finances, they are unable to buy pesticide or other chemicals. The delay in handling this kind of situation can destroy their harvest altogether. Therefore, a future investigation will be carried out to find out how microfinance facility can be provided to the farmers via the MBIS.

Event Calendar: This tool will be developed to link the activities of a farming cycle to a calendar. The MBIS application produces types of resources and their quantities. It also produces details of the suppliers from whom farmers can purchase these items. The event calendar will give the farmers a reminder with necessary details. It will help farmers plan their farming activities.

Discussion Forums: To further enhance the relationships among farmers, a discussion forum tool will be implemented. Farmers often speak with each other when they have common issues. Sometimes they buy as a group a larger quantity of fertilizer or pesticide and a platform such as a discussion forum may help them maintain social and commercial relationships.

7.5.2 Application of the empowerment framework in other domains and countries

The following two recent research projects use the empowerment framework developed in this thesis. One project is in a different country (India) and different domain (Chronic disease management).

a) Indian Venture Capital Company has signed a MoU to create a start-up company to deploy the system initially in India and other companies.
    - This project is in the same agriculture domain. However, there are many different variables such as type of crops, weather details, diseases, fertiliser, pesticides. Etc. The empowerment framework designed in this thesis can be used to develop a system that can be used to empower the farmers in a different country like India to achieve their meaningful goals. The biggest challenge in this case would be to develop an application which would be in harmony with social dynamics of much larger population such as India. Because of the high population, the Indian farming community has a corporate structure to manage and monitor their farming activities. Therefore, the individual empowerment as well as community empowerment will be taken into consideration when developing empowerment-oriented applications for societies like this.

b) The Capital Markets Cooperative Research Centre (CMCRC/Health) in Australia has been exploring to adopt to manage chronic disease, starting with diabetes.
    - This project is in the health domain. The meaningful goals in this domain are more directed towards as how to manage diabetes of a person to maintain quality in person's life. In this project too, the empowerment framework can be used to design applications with empowerment-oriented processes with actionable and customized information with many choices. In addition, the

participation of support networks such as healthcare workers will be taken in to consideration. The main challenge in this domain would be to understand how chronic disease affects decision making process and the influence of support networks.

7.6 Limitations

As a part-time PhD student, I have benefited tremendously from being part of a collaborative group. It has given me the opportunity to work collaboratively with other researchers from different countries, learn and discuss new ideas and issues together. As many of the other students in the collaborative group were full time PhD students, I too had to work like a full-time student to meet the targets as the goals of the individual projects were all linked. In addition, being part of a group has taken a way the loneliness of the PhD journey.

One limitation was the sample size of 30 farmers in our two field trials in 2015. The number of farmers participated in the field trials in December 2012, December 2013, March 2015 and September 2015 was 32, 50, 30 and 30 respectively. About same 30 farmers participated in all four field trials. In all occasions, farmers had to travel from their villages to the designated places to meet the research team to conduct the field trial. The duration of the field trials varied between 1.5 hours to 2.5 hours. With their travelling time, each farmer spent four hours at each field trial approximately. Despite of the challenges they face every day, these farmers spent their valuable time they normally spend on their livelihood activities on these field trials. There was no incentive for them to attend these field trials. They only showed their willingness and curiosity. Therefore, under these difficult circumstances, to have a sample size of 30 farmers for this research was considered as reasonable.

The extent and volume of data collection was further limited by various logistical issues including access, timing and funding constraints. Access to participants had to be done through the agricultural officers and involved travel to remote areas of Sri Lanka. Trials needed to be conducted 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.

7.7 Final Remarks

This thesis was driven by a desire to address the hopelessness experienced by many Sri Lankan farmers and which led some to feel they had no choice but suicide. Going forward, the MBIS artefact aims to reach many more farmers and indeed with the interest and involvement of the Sri Lankan Government, this future outcome is likely. However, the motivation to create and evaluate an empowerment framework for MBIS goes beyond improving the livelihood of Sri Lankan farmers. The motivation and ongoing vision is that this work will impact not just farmers and not just in Sri Lanka but other nations and people who in the future will benefit from applications designed specifically with their empowerment in mind by researchers, designers and developers utilizing the empowerment framework offered in this thesis.

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9 Appendix A

Scenario Design

Actor for scenario one: Bandara is a 40-year-old farmer who lives in a village near Polonnaruwa in Sri Lanka. He studied up to Advanced Level class in school and can read and write well in his native language. He uses a basic mobile phone for voice communication and to receive market prices. Sometimes he sends SMS too. After his schooling period, there weren't any other jobs available for him to take up. Therefore, he chose paddy farming even though he knew he could not earn enough money to live.

Scenario One:(Senaratne 2005; Sunil 2012) Bandara's land is 2.5 acres that produces 2,500 kg of paddy. The government buys only 500Kg/acre and the maximum amount that he can sell to the government is 1250 Kg. When selling to the government, Bandara must meet the buying standards of the government such as the moisture content which must be lower than 14% and there should not be any black seeds. Sometimes, even if he satisfied the buying standards of the government, it takes a while for him to receive a cheque for his sale. When he cannot sell his paddy to the government, he must sell it to the private traders who pay him very low prices. Bandara does not have money to buy fertilizer and chemicals at the beginning of crop cycles. He buys them from private traders on loan basis at higher prices. After he sells his paddy he pays off some of these expenses, he does not have enough money to live. He borrows money from private money lenders and as a result he has become more indebted to private traders and money lenders. Private money lenders charge exorbitant interest rates of 30% to 50% for a 5-6 month growing season. They collect the proportion of the crop equivalent to the money loaned, plus the interest just after the harvest.

Actor for scenario Two: Anura is a 35-year-old farmer who lives in a village near Dambulla in Sri Lanka. He is a tomato grower who has a good knowledge on how to grow tomatoes. He had to stop studying at school due to economic difficulties at home. He and his brothers were compelled to farm on a rented land as there was no other alternative. He can read and write well in his native language and can speak and understand some English too. He likes using his basic mobile for communicating and keen to learn the new technology.

Scenario Two:(Gunasekara 2012; WSWS 2011) Anura and his brothers' farm on rented land and they need to pay a higher amount for the rent at the end of the season. He cannot get a loan from the state bank as they need at least Rs50,000 ($500) fixed deposit account, or the land deed as security for the mortgage, both of which they do not have. Anura does not have a prior knowledge of market conditions. Often there is an over-supply of tomatoes at the market and when that happens he cannot sell the tomatoes at a reasonable price. As he cannot afford to transport back his unsold produce to the farm, he has no other choice except to dump it at the bins in the market. Recent introduction of a new law to transport vegetables in plastic crates has made his situation worse. Earlier he used sacks to transport his tomatoes. With the new law, he needs to spend 830% more money to transport his produce to the market.

Actor for scenario three: Shanthi is a 35-year-old widower and a mother of two young children. She lives in a village near Welikanda. For generations, her family has been paddy farmers. She went to school and she can communicate well in her native language. She got married young and supported her husband in farming activities while raising her family. Unfortunately, her husband who was a paddy farmer committed suicide as he could not

pay off the money that he borrowed. Shanthi does not own a mobile phone and does not know how to use it. But her husband had one and she knows that a mobile phone is used to talk to others.

Scenario Three:(Senaratne 2005) Since her husband committed suicide, Shanthi does not have a proper income now. Sometimes her neighbours give her some assistance. Shanthi is hard working and she starts to grow vegetables and fruits in her backyard. But she does not have a very good knowledge of farming activities. As she owns the paddy field, she wants to lease it to other farmers. Sometimes other farmers take advantage from her situation by bargaining the price on the lease. Because of the lack of a proper income, she fears that she may not be able to send her children to school for long as she cannot afford these expenses.

Scenarios Analysis – Claims of Scenario One

Situation Features	Pros (+) and Cons (-)	Change needed
Farmer chooses farming as a job.	(+) Farmer is employed. (-) Paddy farming is not his choice.	Job satisfaction
Farmer buys fertilizer and chemicals at the beginning of crop cycles from a private trader on a loan.	(-) Farmer goes in to debt. (-) Farmer does know about other ways to buy fertilizer and chemicals without going in to debt.	Financial security, access to information to make informed decisions, personalised information, alternative solutions community support
Farmer sells his paddy to the government.	(+) Farmer receives a good price for some of his paddy. (-) Farmer cannot sell his entire paddy to the government. (-) Farmer is trapped in poverty.	Financial security, access to information to make informed decisions, alternative solutions
Farmer sells his paddy to the private trader.	(-) Farmer is forced to sell some or his entire paddy to private traders at a lower price. (-) Farmer has lack of knowledge on other traders and market conditions. (-) Farmer is trapped in poverty.	Financial security, access to information to make informed decisions, alternative solutions

Scenarios Analysis – Claims of Scenario Two

Situation Features	Pros (+) and Cons (-)	Change needed
Farmer chose to grow tomatoes on a rented land.	(+) Farmer uses his wealth of knowledge that he has gained over the years to grow tomatoes. (-) Farmer's knowledge on how to grow tomatoes may not be up-to-date, accurate or complete. (-) Farmer pays a rent for the land at the end of the season.	Access to information to make informed decisions, Financial security Personalised information Alternative solutions
Farmer takes his produce to the market when the supply of tomatoes is high which is unknown to him.	(-) Farmer does not know market conditions beforehand. (-) Selling price goes down. (-) Farmer dumps unsold tomatoes at the market. (-) Farmer does not know alternative solutions (-) Wastage of tomatoes. (-) Farmer feels anxious, angry and frustrated that he could not sell his produce well.	Access to information to make informed decisions, personalised information, financial security, alternative solutions
The government introduces a new law to use plastic crates instead of sacks to transport vegetables.	(+) Vegetable and fruit wastage due to poor transportation methods may be reduced by 5% - 40%. (-) Farmer cannot afford high transportation costs introduced by transport traders. (-) Farmer does not know alternative, cheap and efficient packaging methods.	Financial security, access to information to make informed decisions, alternative solutions

Scenarios Analysis – Claims of Scenario Three

Situation Features	Pros (+) and Cons (-)	Change needed
Shanthi is a single mother.	(-) Helpless family in emotional trauma (-) No proper income for the family to survive (-) Children may stop going to school	Disaster recovery plan, financial security, community support personalised information
Shanthi grows vegetable in her backyard.	(+) helps to feel she in some control in her life. (+) Uses her limited knowledge of farming in practice. (+) Brings a little income to the family. (-) Lack of knowledge of farming may not bring a good outcome to the family.	Education, access to information to make informed decisions, alternative solutions
Shanthi leases her paddy land to other farmers.	(+) Brings some income to the family. (-) need to deal with social issues relating to a young, widowed woman having to deal with other men	Safety and security, alternative solutions, personalised information

Scenario Transformation

Negative Claim	Possible positive outcome via empowerment activities in MBIS
Scenario One: (-) Farmer is forced to sell some/ entire paddy to private traders at a lower price. (-) Farmer has lack of knowledge on other traders and market conditions. **Scenario Two:** (-) Farmer does not know market conditions beforehand.	Farmer sends a query to the proposed MBIS to find out the traders who can buy his paddy. The query searches the dynamic knowledge database to provide aggregated, real-time information about the traders, the type of paddy they buy, selling price and geographical locations. Farmers can access the discussion board and enquire about the experiences that other farmers had dealing with a particular trader, different transport mechanisms and associated costs.
Scenario One: (-) Farmer does know alternatives to purchase fertilizer and chemicals without going in to debt. (-) Farmer trapped in poverty.	When farmers need to buy fertilizer and chemicals, they can pool their resources to buy them in bulk. They can plan and coordinate these activities as a community activity to help each other rather than seeking assistance from a private money lender.
Scenario Two: (-) Farmer cannot afford to take unsold tomatoes back to the farm.	Farmer can query the existing knowledge base of MBIS to get advice on the type of transport mechanisms available, cost of transport and availability of pooled transportation facilities.
Scenario Two (-) Farmer's knowledge on how to grow tomatoes may not be up-to-date, accurate or complete.	When a farmer sends a query to MBIS via their mobile phone, MBIS can recognise the location of the farmer. Dynamic knowledge-base of MBIS can provide an indication of how many other farmers would be growing the same type of tomatoes and other types of crops that are grown in that area and by how many farmers. The system can also provide other necessary information that is helpful for a particular stage. For example; in a deciding stage of a crop cycle, information on weather conditions, high yield crops and crop diseases. That would give a farmer the choice of deciding whether to continue with growing tomatoes or choose a new crop to grow in a season.
Scenario Two (-) Farmer does not know alternative, cheap and efficient packaging methods.	Via discussion forums, local farming community can start to discuss their ideas about how to find a sustainable solution to packaging problem. They can start using their ideas to build relationships with other organisations to find a reasonable solution.
Scenario Two (-) Farmer does not know alternative solutions other than selling tomatoes (-) Wastage of tomatoes.	At selling stage, farmers can query MBIS to know about other traders who use tomatoes for secondary functions such as making tomato sauce/juice/paste. This will help a farmer to decide whether to sell all his tomatoes or sell it to a trader for secondary purposes.
Scenario Three: (-) Helpless family in emotional trauma (-) No proper income for the family to survive (-) Children may stop going to school (-) Lack of knowledge on farming may not bring a good outcome to the family. (-) need to deal with social issues relating to young, widowed women having to deal with male farmers.	MBIS can assist farmers to organise activities that would help them to deal with situations such as a death in a family, sickness and natural disasters such as drought and floods. MBIS can provide them with some knowledge on how to create community groups and disaster recovery plans. For example, farmers can subscribe a small percentage of their income to a farmer's group towards such situations. Discussion forums can be used for brainstorming to find solutions to these situations. They can use an online, anonymous voting system to nominate their leaders without bias. That gives community groups the power to find the solutions in their own environment. Power of such community groups would help men and women to feel that they are not isolated and minimise disruptions to their livelihoods.

10 Appendix B

Questionnaire - Technology Usage of Farmers in Sri Lanka

Field Trial: December 2012

The main objective of this study is to investigate the current technology usage of farmers in Sri Lanka and field trial and receive feedback on the prototype of business planning application. This information will be useful to design and implement a farmer-focused business planning application.

This questionnaire is anonymous. All the information given by you will be kept confidential. Participation of this study is voluntary and if you choose to withdraw, you can withdraw at any time. Answering all the questions is not compulsory; you may leave any questions that you do not want to answer.

Part A and Part B of this questionnaire have questions that are related to demographic details of the participant and their technology usage. The questions in Part C are related to gathering the experiences of participants' use of the prototype of business planning application.

PARTA – Participant details:

Please circle the most appropriate answer.

1. Can you please tell me your age group?
    a. Under 21
    b. 21-30
    c. 31-40
    d. 41-50
    e. Over 51

2. Gender
    a. Male
    b. Female

3. What is your marital status?
    a. Married
    b. Widowed
    c. Divorced
    d. Single

4. What educational level have you reached at the moment?
    a. Primary Education
    b. Secondary (up to GCE Ordinary Level)

c. GCE Advanced Level
d. Diploma Level
e. University graduate
f. Post graduate
g. No formal education

5. What is your main occupation?
    a. Farmer
    b. Fisherman
    c. Trade
    d. Manufacturing
    e. Private sector – unskilled
    f. Private sector – skilled
    g. Public sector – unskilled
    h. Private sector – skilled

6. How would you categorise your financial status?
    a. Self-employed
    b. Employed on permanent contract
    c. Employed on temporary contract
    d. Casual
    e. Employed on daily basis

7. How often have you changed your employment in the past?
    a. Very often
    b. Fairly often
    c. Not very often
    d. Never

8. How secure do you feel in your present employment/occupation?
    a. Very secure
    b. Fairly secure
    c. Neither secure nor insecure
    d. Fairly insecure
    e. Very insecure

9. Is your home
    a. owned
    b. owned with mortgage
    c. rented
    d. given in exchange for services
    e. sharing with relatives/parents

10. Do you use any land for farming?
    a. Yes
    b. No

11. What is the ownership of this land?
    a. Owned
    b. Rented
    c. Used with no formal agreement
    d. Other (please specify) _____

12. In your work or livelihood, do you need to use any particular tools or equipment?
    a. Yes
    b. No

13. What tools or equipment do you need? Please write your answer in the space provided below.

Tool A	
Tool B	
Tool C	

14. Which of these tools or equipment do you own (either individually or collectively), rent, borrow or not have any access to?
    a. Own individually
    b. Own collectively
    c. Rent individually
    d. Borrow
    e. Do not have any access to

15. Have you ever borrowed money from another person or institution?
    a. Yes
    b. No

16. Are you in debt to anyone at the moment?
    a. Yes
    b. No
17. How indebted would you say you are at the moment?
    a. Extremely indebted
    b. Very indebted
    c. Fairly indebted
    d. A little indebted

18. Do you feel you struggle to repay your debts you have?
    a. Yes, I struggle greatly
    b. Yes, I struggle a little
    c. No, I do not struggle at all

19. Are you a member of any organization or group
    a. Yes
    b. No

20. Which of the following groups are you a member of (formally or informally)?
    a) Farmer/fisher group or cooperative
    b) Traders or business association
    c) Trade union or labor union
    d) Village committee
    e) Religious or spiritual group (e.g. temple, church, mosque, religious study group)
    f) Political group
    g) Cultural group or association (e.g. arts, music, theatre, film)
    h) Finance, credit or savings group
    i) Health group
    j) Sports group
    k) Youth group

Questions 21, 22, 23, 24 and 25 refer to the organisations/groups identified in Q20. Please select your answer from the list in Q20.

21. Which of these organisations/groups influence your farming decisions and practices? Please specify up to three. Select these organisations/groups from Q20 and put the most influential organisations/groups in Org/Group 1 box, second most influential organisations/groups in Org/Group 2 box, ..etc

Org/group 1	Org/group 2	Org/group 3

22. How much does being a member of these groups benefit you individually?
    a. Greatly
    b. Fairly
    c. A little
    d. Not at all

Org/group 1	Org/group 2	Org/group 3

23. What is the most important benefit, if any, that you feel you gain from being a member of these groups? Please write your answer in the space provided below.

Org/group 1	
Org/group 2	
Org/group 3	

24. For each of these three important groups, how effective overall is the group's leadership?
    a. Very effective
    b. Fairly effective
    c. Not effective

Org/group 1	Org/group 2	Org/group 3

25. How much influence do you have when each group chooses its leaders?
    a. A lot of influence
    b. Some influence
    c. A little influence
    d. No influence

Org/group 1	Org/group 2	Org/group 3

26. Describe how farming decisions are made. Describe who is involved and what role they play? Please write your answer in the space provided below.

27. How are leaders in group selected?
    a. By an outside person or organization
    b. Current leader chooses the new leader
    c. By a small group of numbers
    d. By decision or vote of all members
    e. Other (please specify)
    f. Don't know / not sure

PART B – INFORMATION AND TECHNOLOGY USAGE- Please circle the most appropriate answer.

Access to Information

1. How often in the last month have you read a newspaper or had one read to you?
    a. Everyday
    b. A few times a week
    c. Once a week
    d. Less than once a week
    e. Never

2. How often do you listen to the radio?
    a. Everyday
    b. A few times a week
    c. Once a week
    d. Less than once a week
    e. Never

3. How often do you watch television?
    a. Everyday
    b. A few times a week
    c. Once a week
    d. Less than once a week
    e. Never
4. In general compared to five years ago, how would you describe your access to information now?
    a. Improved
    b. Deteriorated
    c. Stayed about the same
    d. Don't know / not sure

Technology Usage: Mobile Phone

1. Do you own a mobile phone?
    a. Yes
    b. No
2. How many working mobile phones do you own?
    a. 1
    b. 2
    c. 3
3. How many working mobile phones do your household own?
    a. 1
    b. 2
    c. 3
    d. 4

4. For what purposes do you use your mobile?
    a. Making phone calls
    b. Receiving phone calls
    c. Sending/receiving SMS (text messages)
    d. Sending/receiving MMS (picture messages)
    e. Browsing the Internet / visit websites/search etc.
    f. Taking photos
    g. Play games
    h. Listen to the radio
    i. Listen to music files
    j. to organize my work using the organizer
    k. check my bills
    l. access Facebook

5. The following services can be accessed via mobile phones or computers via the Internet. What are the services that you are aware of
    a. banking and financial services
    b. paying bills (electricity bill, water bill, telephone bill..etc)
    c. medical services (channelling a doctor, check healthcare packages, telemedicine. Etc)
    d. competition polls or participation in other live programs on TV or radio
    e. entertainment related activities (sports updates, TV and movie updates,
    f. livelihood related information (price alerts, market information, stock updates, TV and movie updates. Etc)
    g. general information services (news, weather. Etc)

Technology Usage: Internet and Computer usage

1. Have you used a computer from any location during last 12 months?
    a. Yes
    b. Can't remember when but I have used one before
    c. No
    d. Don't know what a computer is
2. Have you used the Internet from any location during last 12 months?
    a. Yes
    b. Can't remember when but I have used it before
    c. No
    d. No, but someone else searched the Internet to get the information I needed
    e. I haven't heard of the Internet
3. Which one of these statements best describes your internet usage?
    a. At least once a day
    b. At least twice a week
    c. At least once a week
    d. At least two to three times a month
    e. At least once a month
    f. Less than once a month
    g. Do not use the Internet
4. Where have you used the Internet in the last two months?
    a. Home
    b. Work
    c. Place of education
    d. Another person's home
    e. Community Internet access facility
    f. Commercial Internet access facility
    g. Any place via a mobile device (mobile phone or laptop)
        Why do you use the Internet through a mobile phone?
    h. I don't own a computer
    i. I only use it when don't have access to any computer
    j. It gives me more privacy
    k. It is cheaper than using a computer
    l. My computer does not have an Internet connection

PART C

Interview Questions (open ended) - Use of Business Planning Application

Farmers will be asked to use the business planning application. Their experience of using the application will be gathered by interviewing the farmers using the following open-ended questions will be used.

1. At the beginning of your crop cycle, do you carry out a cost – benefit analysis?
    a. Yes (go to 2)
    b. No (go to 6)

2. Do you use any other method/s to find out profit at the end of the crop cycle?

3. Is your predicted profit very different to what you actually receive at the end?

4. What is the main reason for these values to be different?

5. What have you done to investigate why these values are different? (go to 8)

6. What is the reason why you did not carry out a cost-benefit analysis?

7. Do you feel that it would be beneficial to carry out this analysis?

8. Did you understand the functions of the Business Planning Application?

9. Was it easier for you to navigate through various screens?

10. Was it easier for you to understand the instructions?

11. Are there any other expenses that we need to include?

12. Was it useful for you to do this analysis?

13. What are the additional and useful information you may want to receive from an application like this?

THANK YOU VERY MUCH for spending your valuable time with us and participating in this study.

11 Appendix C

Questionnaire - Technology Usage of Farmers in Sri Lanka

Field Trial: November 2013

The main objective of this study is to investigate the current technology usage of farmers in Sri Lanka and further improve the functionality, usefulness and usability of our business planning application.

This questionnaire is anonymous. All the information given by you will be kept confidential. Participation of this study is voluntary and if you choose to withdraw, you can withdraw at any time. Answering all the questions is not compulsory; you may leave any questions that you do not want to answer.

Part A and Part B of this questionnaire have questions that are related to demographic details of the participant and their technology usage. The questions in Part C is general open-ended questions that are related to farming activities, decision making process and participation in community groups. Part D contains questions to gather information about participant's current capabilities in planning various activities in a farming cycle.

PARTA – Participant details:

Please circle the most appropriate answer.

1. Can you please tell me your age group?
    a. Under 21
    b. 21-30
    c. 31-40
    d. 41-50
    e. Over 51

2. Gender
    a. Male
    b. Female

3. What is your marital status?
    a. Married
    b. Widowed
    c. Divorced
    d. Single
4. What educational level have you reached at the moment?
    a. Primary Education
    b. Secondary (up to GCE Ordinary Level)

c. GCE Advanced Level
d. Diploma Level
e. University graduate
f. Post graduate
g. No formal education

5. What is your main occupation?
    i. Farmer
    j. Fisherman
    k. Trade
    l. Manufacturing
    m. Private sector – unskilled
    n. Private sector – skilled
    o. Public sector – unskilled
    p. Private sector – skilled

6. How would you categorise your financial status?
    f. Self-employed
    g. Employed on permanent contract
    h. Employed on temporary contract
    i. Casual
    j. Employed on daily basis

7. How often have you changed your employment in the past?
    e. Very often
    f. Fairly often
    g. Not very often
    h. Never

8. How secure do you feel in your present employment/occupation?
    f. Very secure
    g. Fairly secure
    h. Neither secure nor insecure
    i. Fairly insecure
    j. Very insecure

9. Is your home
    f. owned
    g. owned with mortgage
    h. rented
    i. given in exchange for services
    j. sharing with relatives/parents
    k.

10. Do you use any land for farming?
    c. Yes
    d. No

11. What is the ownership of this land?
    e. Owned
    f. Rented
    g. Used with no formal agreement
    h. Other (please specify) _____

12. Have you ever borrowed money from another person or institution?
    c. Yes
    d. No

13. Are you in debt to anyone at the moment?
    c. Yes
    d. No

14. How indebted would you say you are at the moment?
    e. Extremely indebted
    f. Very indebted
    g. Fairly indebted
    h. A little indebted

15. Do you feel you struggle to repay your debts you have?
    d. Yes, I struggle greatly
    e. Yes, I struggle a little
    f. No, I do not struggle at all

16. Are you a member of any organization or group?
    c. Yes
    d. No

17. Which of the following groups are you a member of (formally or informally)?
    l) Farmer/fisher group or cooperative
    m) Traders or business association
    n) Trade union or labor union
    o) Village committee
    p) Religious or spiritual group (e.g. temple, church, mosque, religious study group)
    q) Political group
    r) Cultural group or association (e.g. arts, music, theatre, film)

s) Finance, credit or savings group
t) Health group
u) Sports group
v) Youth group

PART B – INFORMATION AND TECHNOLOGY USAGE- Please circle the most appropriate answer.

Technology Usage: Mobile Phone

6. Do you own a mobile phone?
    a. Yes
    b. No
7. How many working mobile phones do you own?
    a. 1
    b. 2
    c. 3 or more
8. How many working mobile phones do your household own?
    a. 1
    b. 2
    c. 3
    d. 4 or more

9. For what purposes do you use your mobile?
    a. Making phone calls
    b. Receiving phone calls
    c. Sending/receiving SMS (text messages)
    d. Sending/receiving MMS (picture messages)
    e. Browsing the Internet / visit websites/search etc.
    f. Taking photos
    g. Play games
    h. Listen to the radio
    i. Listen to music files
    j. to organize my work using the organizer
    k. check my bills
    l. access Facebook

10. The following services can be accessed via mobile phones or computers via the Internet. What are the services that you are aware of
    a. banking and financial services
    b. paying bills (electricity bill, water bill, telephone bill..etc)
    c. medical services (channelling a doctor, check healthcare packages, telemedicine. Etc)
    d. competition polls or participation in other live programs on TV or radio
    e. entertainment related activities (sports updates, TV and movie updates,

f. livelihood related information (price alerts, market information, stock updates, TV and movie updates. Etc)
g. general information services (news, weather. Etc)

Technology Usage: Internet and Computer usage

5. Have you used a computer from any location during last 12 months?
    a. Yes
    b. Can't remember when but I have used one before
    c. No
    d. Don't know what a computer is
6. Have you used the Internet from any location during last 12 months?
    a. Yes
    b. Can't remember when but I have used it before
    c. No
    d. No, but someone else searched the Internet to get the information I needed
    e. I haven't heard of the Internet
7. Which one of these statements best describes your internet usage?
    a. At least once a day
    b. At least twice a week
    c. At least once a week
    d. At least two to three times a month
    e. At least once a month
    f. Less than once a month
    g. Do not use the Internet

8. Where have you used the Internet in the last two months?
    a. Home
    b. Work
    c. Place of education
    d. Another person's home
    e. Community Internet access facility
    f. Commercial Internet access facility
    g. Any place via a mobile device (mobile phone or laptop)
        Why do you use the Internet through a mobile phone?
    h. I don't own a computer
    i. I only use it when don't have access to any computer
    j. It gives me more privacy
    k. It is cheaper than using a computer
    l. My computer does not have an Internet connection

PART C – General Interview Questions

1. Can you explain your experience with the last cultivation?
2. What circumstances and/or events affected the last cultivation?
3. Which of those circumstances and/or events did you have some control over and which of them did you have little or no control over
4. How did you find solutions in these circumstances and/or events?
5. Did you have any help from others and what were they?
6. What were your expectations for the last cultivation?
7. Looking back at the last cultivation, what might you have done differently if you knew then what you know now? What stopped you making those decisions at the time?
8. Can you explain how farming decisions are made? Who is involved and what role do they play?
9. Can you describe the leadership skills and commitment of the leaders in the groups/committees you are attached to?
10. What is the most important benefit, if any, that you feel you gain from being a member of these groups?
11. For the last cultivation did you change your mind about how to do something based on advice or direction from other people, including leaders? How did that change affect the success of the cultivation?

PART D - Agriculture Planning Self-Efficacy

Please rate how certain you are that you can plan various situations in the farming cycle. Rate your degree of confidence by recording a number from 0 to 100 using the scale given below**.**

0	10	20	30	40	50	60	70	80	90	100
Cannot do				Moderately can do					Highly certain can do	

1. I can predict almost all the expenses in a crop cycle.
2. I keep a record of all the expenses.
3. I can decide various types of fertiliser/pesticide/chemical that I need to use in various stages of crop cycle.
4. I know how much fertiliser/pesticide/chemical that I need to use in various stages of crop cycle.
5. I am aware of various diseases that may damage my plants.
6. I know which pesticide to use for crop disease.
7. I know how much water I need to grow my crop.
8. I am aware of how to organize water supply to my farm.
9. I can organize required labor during crop cycle.
10. I can organize various farming machines during crop cycle.
11. I know a large number of suppliers who sell fertiliser/pesticide/chemical.
12. I know how to contact different suppliers of fertiliser/pesticide/chemical.
13. I can keep a record of various suppliers.
14. I can decide how to apply for a loan.
15. I know how to apply for a loan.
16. I am good at paying off my loan on-time.
17. I have a good understanding of different types of packaging that I need to use when transporting my crop to the markets.
18. I can organize transportation.
19. I am aware of different markets other than local markets.
20. I can compare the market prices of different seasons.
21. I can make decisions on selling price of my crop.

THANK YOU VERY MUCH for spending your valuable time with us and participating in this study.

12 Appendix D

Questionnaire - Technology Usage of Farmers in Sri Lanka

Field Trials: March 2015 and September 2015

The main objective of this study is to investigate the current technology usage of farmers in Sri Lanka and further improve the functionality, usefulness and usability of our business planning application.

This questionnaire is anonymous. All the information given by you will be kept confidential. Participation of this study is voluntary and if you choose to withdraw, you can withdraw at any time. Answering all the questions is not compulsory; you may leave any questions that you do not want to answer.

Part A and Part B of this questionnaire have questions that are related to demographic details of the participant and their technology usage. The questions in Part C is to assess the current knowledge of participants' of farming, the competence and confidence of the participants in planning farming activities, the motivation to do farming and their sense of control in farming life.

PARTA – Participant details:

Please circle the most appropriate answer.

1. Can you please tell me your age group?
    a. Under 21
    b. 21-30
    c. 31-40
    d. 41-50
    e. Over 51

2. Gender
    a. Male
    b. Female

3. What is your marital status?
    a. Married
    b. Widowed
    c. Divorced
    d. Single

4. What educational level have you reached at the moment?
    a. Primary Education
    b. Secondary (up to GCE Ordinary Level)
    c. GCE Advanced Level
    d. Diploma Level
    e. University graduate
    f. Post graduate
    g. No formal education

5. What is your main occupation?
    q. Farmer
    r. Fisherman
    s. Trade
    t. Manufacturing
    u. Private sector – unskilled
    v. Private sector – skilled
    w. Public sector – unskilled
    x. Private sector – skilled

6. How would you categorise your financial status?
    k. Self-employed
    l. Employed on permanent contract
    m. Employed on temporary contract
    n. Casual
    o. Employed on daily basis

7. How often have you changed your employment in the past?
    i. Very often
    j. Fairly often
    k. Not very often
    l. Never

8. How secure do you feel in your present employment/occupation?
    k. Very secure
    l. Fairly secure
    m. Neither secure nor insecure
    n. Fairly insecure
    o. Very insecure

9. Is your home
    l. owned
    m. owned with mortgage
    n. rented
    o. given in exchange for services
    p. sharing with relatives/parents

10. Do you use any land for farming?
    e. Yes
    f. No

11. What is the ownership of this land?
    i. Owned
    j. Rented
    k. Used with no formal agreement
    l. Other (please specify) _____

12. Have you ever borrowed money from another person or institution?
    e. Yes
    f. No

13. Are you in debt to anyone at the moment?
    e. Yes
    f. No

14. How indebted would you say you are at the moment?
    i. Extremely indebted
    j. Very indebted
    k. Fairly indebted
    l. A little indebted

15. Do you feel you struggle to repay your debts you have?
    g. Yes, I struggle greatly
    h. Yes, I struggle a little
    i. No, I do not struggle at all

16. Are you a member of any organization or group?
    e. Yes
    f. No

17. Which of the following groups are you a member of (formally or informally)?
    a) Farmer/fisher group or cooperative
    b) Traders or business association
    c) Trade union or labor union
    d) Village committee
    e) Religious or spiritual group (e.g. temple, church, mosque, religious study group)
    f) Political group
    g) Cultural group or association (e.g. arts, music, theatre, film)
    h) Finance, credit or savings group
    i) Health group
    j) Sports group
    k) Youth group

PART B – INFORMATION AND TECHNOLOGY USAGE- Please circle the most appropriate answer.

Technology Usage: Mobile Phone

1. Do you own a mobile phone?
    a. Yes
    b. No
2. How many working mobile phones do you own?
    a. 1
    b. 2
    c. 3 or more
3. How many working mobile phones do your household own?
    a. 1
    b. 2
    c. 3
    d. 4 or more

4. For what purposes do you use your mobile?
    a. Making phone calls
    b. Receiving phone calls
    c. Sending/receiving SMS (text messages)
    d. Sending/receiving MMS (picture messages)
    e. Browsing the Internet / visit websites/search etc.
    f. Taking photos
    g. Play games
    h. Listen to the radio
    i. Listen to music files
    j. to organize my work using the organizer
    k. check my bills
    l. access Facebook

5. The following services can be accessed via mobile phones or computers via the Internet. What are the services that you are aware of
    a. banking and financial services
    b. paying bills (electricity bill, water bill, telephone bill..etc)
    c. medical services (channelling a doctor, check healthcare packages, telemedicine. Etc)
    d. competition polls or participation in other live programs on TV or radio
    e. entertainment related activities (sports updates, TV and movie updates,
    f. livelihood related information (price alerts, market information, stock updates, TV and movie updates. Etc)
    g. general information services (news, weather. Etc)

Technology Usage: Internet and Computer usage

9. Have you used a computer from any location during last 12 months?
    a. Yes
    b. Can't remember when but I have used one before
    c. No
    d. Don't know what a computer is
10. Have you used the Internet from any location during last 12 months?
    a. Yes
    b. Can't remember when but I have used it before
    c. No
    d. No, but someone else searched the Internet to get the information I needed
    e. I haven't heard of the Internet
11. Which one of these statements best describes your internet usage?
    a. At least once a day
    b. At least twice a week
    c. At least once a week
    d. At least two to three times a month
    e. At least once a month
    f. Less than once a month
    g. Do not use the Internet

12. Where have you used the Internet in the last two months?
    a. Home
    b. Work
    c. Place of education
    d. Another person's home
    e. Community Internet access facility
    f. Commercial Internet access facility
    g. Any place via a mobile device (mobile phone or laptop)

    Why do you use the Internet through a mobile phone?

h. I don't own a computer
i. I only use it when don't have access to any computer
j. It gives me more privacy
k. It is cheaper than using a computer
l. My computer does not have an Internet connection

PART C – Sense of Control, Motivation and Self-Efficacy Questions

(a) Sense of Control – When thinking about your work, please use the scale below to indicate how strongly you agree or disagree with each of the following statements

1=Agree strongly, 2=Agree somewhat, 3=Agree a little, 4=Don't know, 5=Disagree a little, 6=Disagree somewhat, 7=Disagree strongly

1. I am not afraid to voice my opinions even when they are in opposition to the opinions of most people
2. My decisions are not usually influenced by what everyone else is doing.
3. I have confidence in my opinions even if they are contrary to the general consensus.
4. Being happy with myself is more important than having others approve of me.
5. I tend to worry what other people think of me.
6. I often change my mind about decisions if my friends and family disagree.
7. It is difficult for me to voice my own opinions on controversial matters.

(b) Motivation: Why do you do your work – Please use the scale below to indicate to what extent each of the following statements corresponds to the reasons why you are presently involved in your work.

1=Agree strongly, 2=Agree somewhat, 3=Agree a little, 4=Don't know, 5=Disagree a little, 6=Disagree somewhat, 7=Disagree strongly

1. Because this is the type of work I chose to do to attain a certain lifestyle.
2. For the income it provides me.
3. Because I derive much pleasure from learning new things.
4. Because I want to succeed at this job, if not I would be very ashamed of myself.
5. For the satisfaction I experience from taking on interesting challenges
6. Because I want to be a "winner" in life.
7. Because it is the type of work I have chosen to attain certain important objectives.
8. For the satisfaction I experience when I am successful at doing difficult tasks.
9. Because this type of work provides me with security.

(c) Agriculture Planning Self-Efficacy

Please rate how certain you are that you can plan various situations in the farming cycle. Rate your degree of confidence by recording a number from 0 to 100 using the scale given below

0 10 20 30 40 50 60 70 80 90 100

Cannot do Moderately can do Highly certain can do

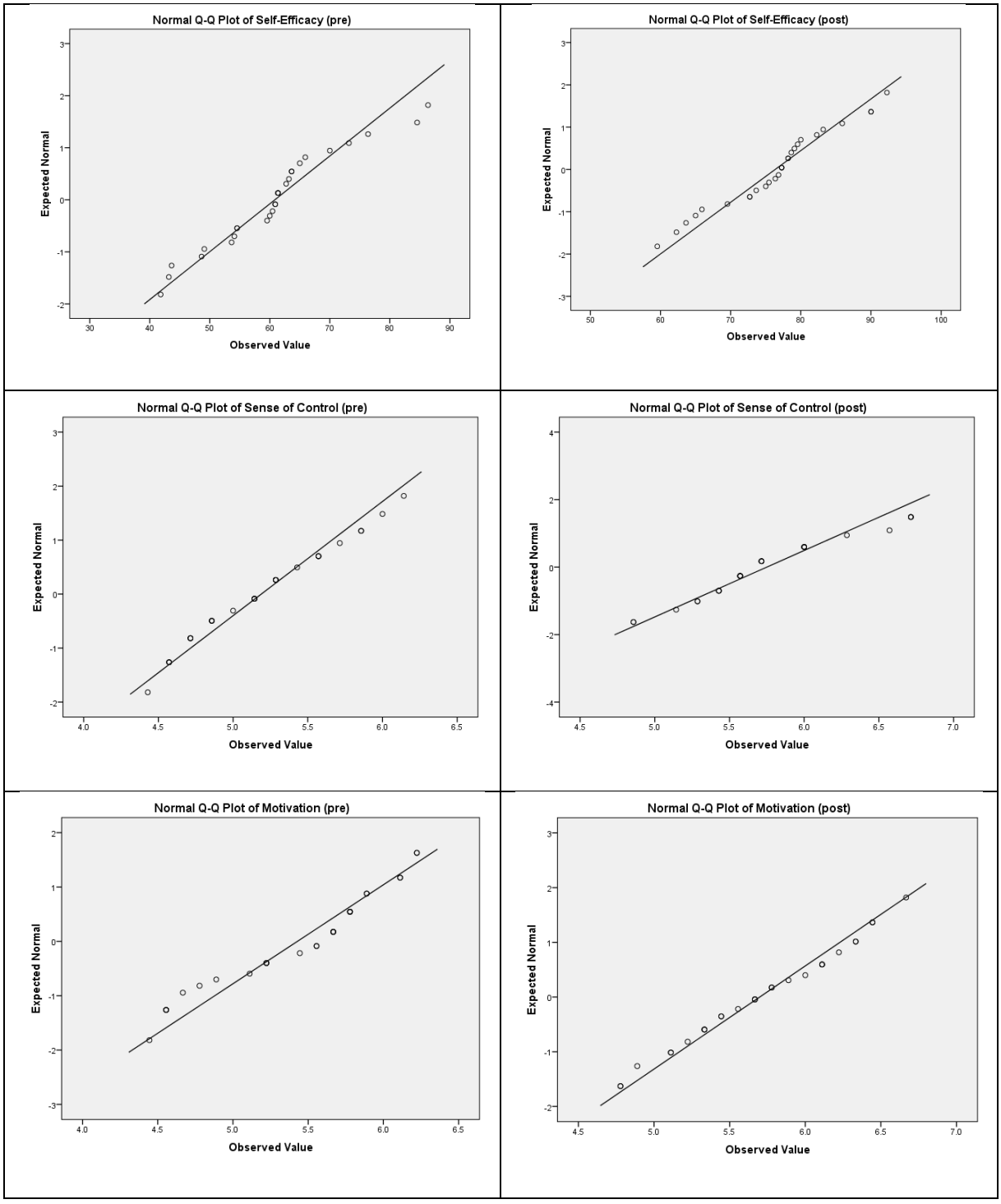
1. I can calculate and predict almost all the expenses in a crop cycle.
2. I can keep a record of all the expenses.
3. I can decide which crop to grow each season.
4. I know of all the crops that grow in my farm.
5. I know of various types of fertiliser/pesticide/chemical that I need to use in various stages of crop cycle.
6. I know how much fertiliser/pesticide/chemical that I need to use in various stages of crop cycle.
7. I can apply various fertiliser/pesticide/chemical correctly.
8. I know of various diseases that may damage my plants.
9. I know of the correct pesticide to apply for crop disease.
10. I know how to control a situation when there is damage by a new disease/pest.
11. I know a large number of suppliers who sell fertiliser/pesticide/chemical.
12. I know how to contact different suppliers of fertiliser/pesticide/chemical.
13. I can keep a record of various suppliers.
14. I can organize labor/farming machines/transportation during crop cycle.
15. I know of different markets other than local markets.
16. I can decide when to take my crops to the market.
17. I can compare the market prices of different seasons.
18. I can make decisions on selling price of my harvest.
19. I know how to sell all the other products in addition to my harvest.
20. I can organise and take actions.
21. I can recover from failures and setbacks.
22. I can exercise influence to change a decision taken by government authorities.

THANK YOU VERY MUCH for spending your valuable time with us and participating in this study.

13 Appendix E

Analysis One:

Q-Q plots:



Results of Wilcoxon signed-rank test:

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Self-Efficacy (post)	28	76.34740260	8.182269107	59.54545455	92.27272727
Sense of Control (post)	28	5.750000000	.5078745002	4.857142857	6.714285714
Motivation (post)	28	5.698412698	.5305975295	4.777777778	6.666666667
Self-Efficacy (pre)	28	60.84415584	10.87798194	41.81818182	86.36363636
Sense of Control (pre)	28	5.188775510	.4730908188	4.428571429	6.142857143
Motivation (pre)	28	5.428571429	.5491101716	4.444444444	6.222222222

Ranks

		N	Mean Rank	Sum of Ranks
Self-Efficacy (pre) - Self-Efficacy (post)	Negative Ranks	27[a]	15.00	405.00
	Positive Ranks	1[b]	1.00	1.00
	Ties	0[c]		
	Total	28		
Sense of Control (pre) - Sense of Control (post)	Negative Ranks	24[d]	14.13	339.00
	Positive Ranks	2[e]	6.00	12.00
	Ties	2[f]		
	Total	28		
Motivation (pre) - Motivation (post)	Negative Ranks	18[g]	15.97	287.50
	Positive Ranks	9[h]	10.06	90.50
	Ties	1[i]		
	Total	28		

a. Self-Efficacy (pre) < Self-Efficacy (post)

b. Self-Efficacy (pre) > Self-Efficacy (post)

c. Self-Efficacy (pre) = Self-Efficacy (post)

d. Sense of Control (pre) < Sense of Control (post)

e. Sense of Control (pre) > Sense of Control (post)

f. Sense of Control (pre) = Sense of Control (post)

g. Motivation (pre) < Motivation (post)

h. Motivation (pre) > Motivation (post)

i. Motivation (pre) = Motivation (post)

Test Statistics[a]

	Self-Efficacy (pre) - Self-Efficacy (post)	Sense of Control (pre) - Sense of Control (post)	Motivation (pre) - Motivation (post)
Z	-4.601[b]	-4.160[b]	-2.374[b]
Asymp. Sig. (2-tailed)	.000	.000	.018

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

14 Appendix F

14.1 Identification of information needs

In order to make informed decisions at different stages of a crop cycle, farmers need access to the relevant and up-to-date agricultural information and knowledge. This information that is generated at different entities by stakeholders should flow to the farmer to achieve the full potential of informed decision-making process. These two important areas were investigated in the overall project (see section 1.5). In this section, we discuss how these important areas were addressed.

- Development of an Agriculture Information Eco System to have an enhanced information flow
- Development of a User Centered Agriculture Ontology

14.1.1 Information flow – Development of an Agriculture Information Eco System to have an enhanced information flow

The field trials we carried out in 2012 and 2013 helped us to understand the current information flow in the farming domain in Sri Lanka (chapter 4). There is an agriculture extension officer who is appointed to each village. This officer visits the farmers often and provides advice and solutions to the issues they are experiencing during their cultivation. This officer is also responsible for gathering farmer data such as the cultivation extent and different crops that the farmers grow. The officer provides this farmer data to the agriculture department. The reports prepared by the agriculture department are provided to other government organisations, research institutes and published on the web. The decision makers use this static information to predict the supply and demand situation, the food security levels in the country and decide on how much to import. However, such important decisions or the data gathered have never been given back to the farmer. Our field trials also revealed that the farmers do not access these websites due

to the low computer literacy and unavailability. Further, the data on the websites were not in a format for the farmers to easily access what they needed. It needed high intellectual skills to search and sort. As a result, farmers were unable to benefit from the data that were available on the websites either.

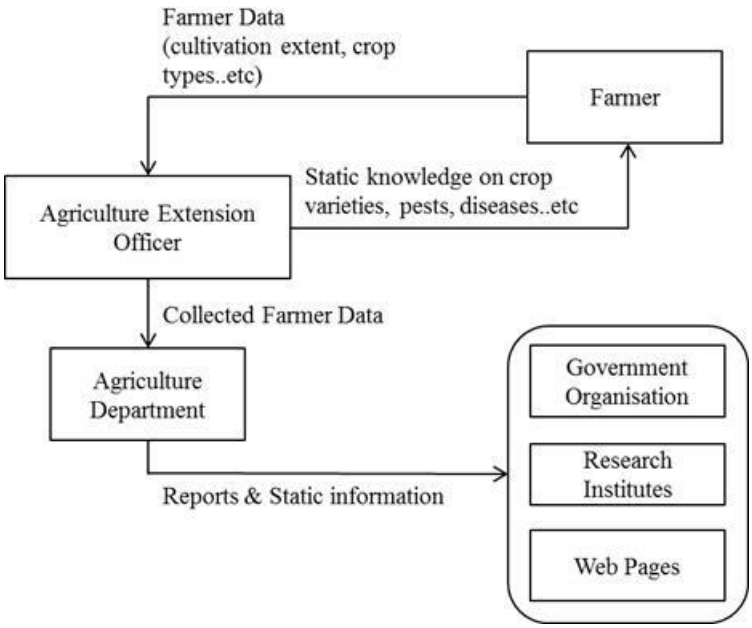


Figure 14-1 :Current Information Flow (De Silva et al. 2012)

The study of De Silva et al (2012) enabled us to find out the information needs of three major phases of the farming cycle: crop choosing/deciding, crop growing and crop selling. It also helped to identify the various stakeholders in each phase. More importantly, the study revealed that there is no proper coordination or information flow among stakeholders. Another important finding was the static and dynamic nature of the information. For example, there was static information such as fertilizer and pesticide details and dynamic information such as crop selling price and the weather. Therefore, to make optimal decisions in this sector, both static and dynamic information were equally important.

Based on the results of the study, a new, farmer-centric information flow model with better interaction and collaboration between all stakeholders of the farming domain was designed (Figure 14-2). This model lets the farmer input some of the essential information that is required by a different set of stakeholders. As a result, it enables the stakeholders to access both static and dynamic information as needed. This model seeks to increase the information visibility and aid the farmer to take optimal decisions at the right time. The improved understanding provided by the model may lead to better outcomes at the selling stage to improve the financial sustainability of the farmers.

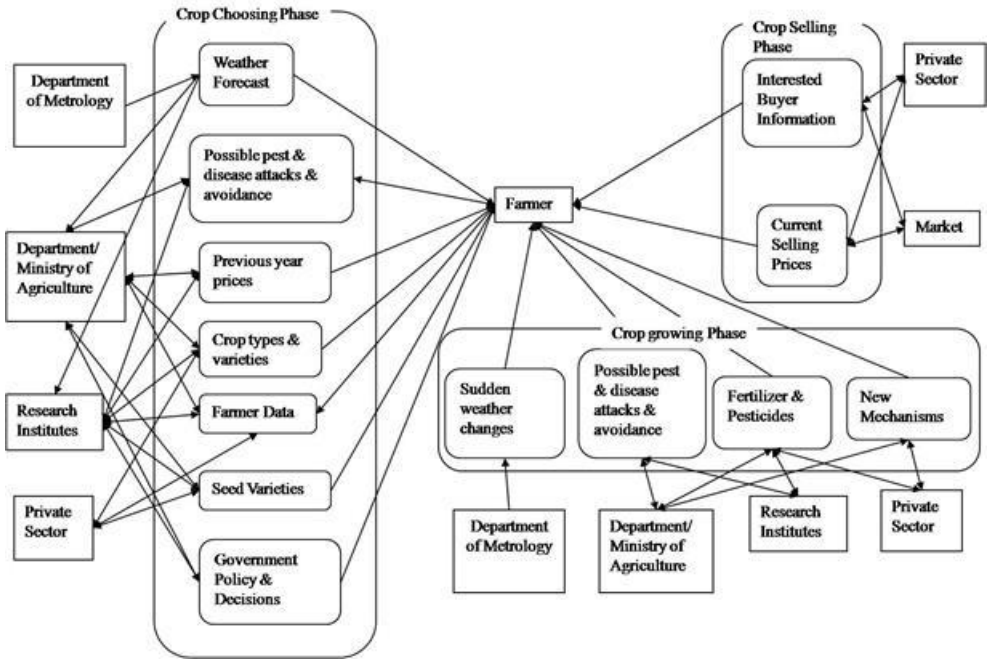


Figure 14-2 : Enhanced Information Flow Model (De Silva et al. 2012)

14.1.2 Up-to-date, relevant and real-time information: Development of a User-Centered Agriculture Ontology

The problem we addressed in the broader context was the overproduction problem (refer to that section). If farmers can be informed of the extent of already planted crops at the time they are deciding on what crops to grow, it will motivate them to avoid growing crops that are already in high production. This will minimise the overproduction problem. A

major research challenge was to discover a reliable way to predict current levels of crop production in real-time to inform the farmers who are in the process of selecting a crop to grow.

Farmers need agricultural information and knowledge such as seasonal weather, best varieties or cultivars, seeds, fertilizers and pesticides, information on pest and diseases, control methods, harvesting and post harvesting methods, accurate market prices, current supply and demand, and information on farming machinery and practices at various stages of the farming life cycle, to make informed decisions (De Silva et al. 2013; Lokanathan and Kapugama 2012). For the Sri Lankan farmers, the majority of farming information is available via government websites, leaflets, agriculture department and mass media. For example, the Agriculture Department; a major stakeholder in the domain has published how to grow various crops, necessary climatic conditions, suitable soil type, watering methods, fertilizer and pesticides to be used etc. as pdf documents on their website (Agriculture 2011) and booklets. However, this information is general in nature, incomplete, heterogeneous and unstructured. It is difficult for the farmers search for information when it is presented this way. As the majority of farmers do not use computers, they were unable to access the information available on the websites. This has resulted in a gap between the farmer's current knowledge and required knowledge. Therefore it was important to re-organise this information and implement an agricultural knowledge repository that is consistent, well-defined, and provide a representation of the agricultural information and knowledge needed by the farmers within their own context (Walisadeera et al. 2014a; Walisadeera et al. 2014b; Walisadeera et al. 2013a; Walisadeera et al. 2013b). As the first attempt of creating a crop ontology, accurate content knowledge was gathered by interviewing the agriculture experts, reviewing research articles and books (Decoteau 2000; Narula and Nainwal 2010) and identifying the authoritative online

data sources.

Farmers want to know "what crops will grow in my farm". Therefore "My farm" was modelled in terms of rainfall, temperature, elevation, soil condition etc. to provide a list of crops that will grow under these conditions. Further, a famer may have specific preferences on the type of the crops to grow such as cash crops, vegetables etc. Therefore, the crop list can be further narrowed down based on the farmer preference. This can further minimise the processing that a farmer should do in the decision-making process.

This process formulated the context for the query and a context model was created to store these parameter values. Then "my farm" was expanded with the corresponding values stored in the context model. The information in the websites and pdf documents were disaggregated into a suitable granular representation so that one can query this information in context.

The information needs of a farmer were formulated as a set of questions (Walisadeera et al. 2013c). *For example: typical questions were: (a) what are the suitable crops to grow? (b) What are the best fertilizers for selected crops?* It was also identified that the way an agriculture expert answers these questions depends on the Sri Lankan farmer context such as *farm environment*, *types of farmers*, *farmers' preferences*, and *farming stages*. The next step was to formulate contextualized questions from the user's information needs (Figure 14-3 - User Context Model). One example of a contextualized question would be - *What are the suitable fertilizers for the Crops which are grown in specified Location*.

From the awareness gained from the field trial of the profit calculator in 2012 and the interviews in 2013, it was evident that both factual and procedural knowledge was very important to the farmers. For example; with regards to a question like *what are the best fertilizers for selected crops,* the names of the fertilizers can be provided. In order to assist

the correct application of fertilizer, additional information such as fertilizer quantity and application method were needed. A fertilizer quantity depends on the many other factors such as the fertilizer types (e.g. Chemical, Organic, or Biological fertilizers), its specific sources (e.g. Nitrogen, Phosphorus, Potassium, etc.), their ratio, location, water source, soil PH range, time of application, and application method. The amount of fertilizer to apply depends on this additional information.

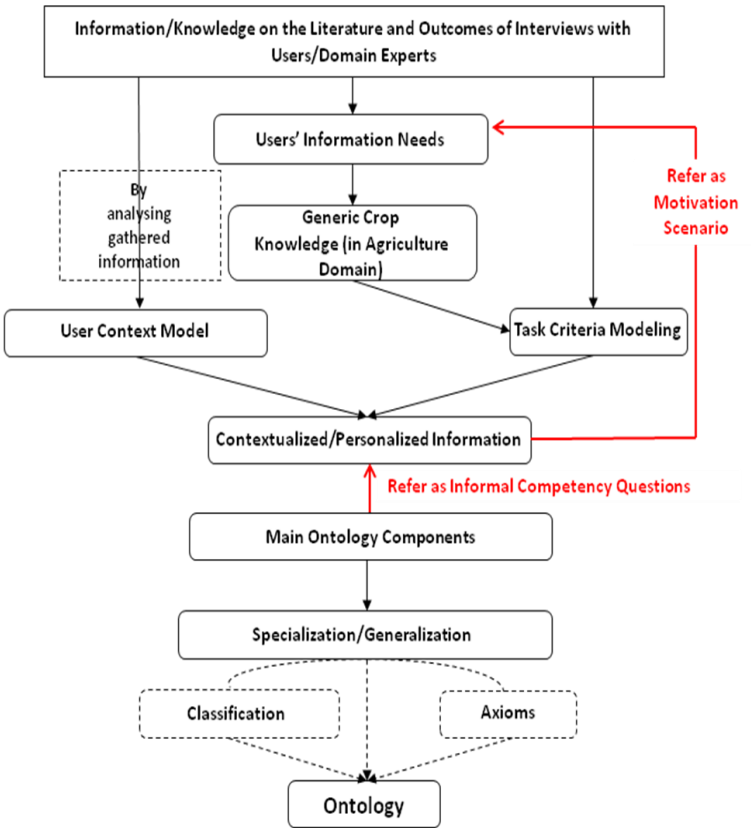


Figure 14-3 : Ontology Design Framework

For the ontology development, the Grüninger and Fox's methodology was employed as a first-order logic (FOL) approach. Being a formal ontology, it is structurally and functionally rich to describe the domain knowledge in context. For the implementation, Protégé as ontology development environment and Web Ontology Language (OWL) as ontology language were selected. Protégé OWL plugin combination is good as a tool for ontology creation because of its scalability and extensibility. Protégé also has powerful

frames and its user interface provides an easy to use environment. Since Description Logics (DL) is a fully decidable fragment of FOL and reduces the complexity when compared with FOL, the DL based approach (OWL 2-DL) is selected to implement the ontology. In this implementation, decidability is very important as we need to retrieve agricultural information and knowledge in user's context.

Table 14-1 : Deriving actionable information from the Ontology

Farmers' Information Needs	**Farmers' Information Needs in Context**	**Generalising Contextualised Information**	**Query in First Order Logic (FOL)**
What are the suitable crops to grow?	***Suitable crops based on the Environment:*** • Which crops are suitable to grow in the 'Dambulla' area? • What are the suitable vegetable crops for 'UpCountry', applicable to the 'Well-drained Loamy' soil, and average rainfall > 2000 mm? ***Suitable crops based on Preferences of Farmers:*** • What Brinjal's varieties can resist the 'Bacterial Wilt' disease?	• Which crops are suitable to grow in specified Location? • What are the suitable *Types of Crops* for specified *Location*, applicable to the specified *Soil types/characteristics*, and other *Conditions* ? • What *Crop's varieties* can resist the specified *Disease*?	(∃x)(Crop(x)) ∧ RegionalArea(Dambulla) ∧ grows(x, Dambulla); (∃x)(Vegetable(x))∧ SoilType(Loamy) ∧ SoilDrainage(Well_dr ained)∧ hasSoilFactor (x,Loamy) ∧ hasSoilFactor(x,Well_dr ained)∧ (∃y Integer(y) ∧ hasMinRainfall(x,y)∧ (2000 ≤ y));

For online knowledge base creation, Resource Description Framework (RDF) was used. A Semantic Web toolkit; ARC2 (appmosphere RDF classes as a SPARQL endpoint) is used to manage the RDF data. The online knowledge base with a SPARQL endpoint was created to share and reuse the domain knowledge that can be queried based on user context. (http://webe2.scem.uws.edu.au/oms/searchInformation.php)

To identify some of the parameters in the context model the MBIS used the GPS capability in a Smartphone. The system captures the geo-coordinates and maps the location of the farm onto an agro ecological zone map. Each agro ecological zone has specific climatic and weather conditions. These values specify the farm context that needs to be used to query the ontological knowledgebase (Mathai and Ginige 2013; Mathai and Ginige 2014).

15 Appendix G – Ethics Application Approval 5201200767

15.1 Ethics Application 5201200767 – Approvable Subject to Conditions

Deborah Richards <Deborah.richards@mq.edu.au> Fri, Oct 19, 2012 at 9:54 AM

To: Faculty of Science Research Office <sci.ethics@mq.edu.au>

Cc: Prof Richie Howitt <richie.howitt@mq.edu.au>, Ms Cathi Humphrey-Hood <cathi.humphrey-hood@mq.edu.au>, Tamara Ginige <Tamara.Ginige@acu.edu.au>

Dear Ethics Cttee,

> RE: Ethics Application Entitled: "Technology Usage of Farmers in Sri Lanka" > Reference number: 5201200767

> The above application was reviewed by the Faculty of Science Human Research

> Ethics Committee. The Committee has requested that the following issues be > addressed before Final Approval can be granted. The issues raised by the > Committee are listed below.

> Research on the project may not commence until your responses have been > reviewed and approved and you have received formal correspondence from the > Committee confirming Final Approval for this project.

> Please address the following issues:

> Q3.3 Please provide the Committee with a list of proposed venues for the > research when this is available.

Tamara will travel to Dambulla, Sri Lanka to meet the farmers and the research will be taken place somewhere in Dambulla. The researcher, Lasanthi De Silva at the University of Colombo, Sri Lanka has agreed to assist with this research (Appendix II). Proposed venue for the research is Agrarian Services Center, Anuradapura Road, Dambulla, Sri Lanka.

> Q5.8 should be left blank.

Fixed.

> Q7.3 Please provide a translation of both the interview questions and the > Information and Consent Form when these are available.

This is still being worked on.

> Generally we require a local contact in for complaints and follow-up. It

> would seem appropriate that Prof Wikramanayake be listed as a local contact > if he is willing. Please advise if this is acceptable and amend your > Information and Consent Form to indicate this.

See updated Information and Consent form. Email consent was received from Prof Wikramanayake to confirm his agreement.

> Appendix B, available on the Ethics website, is required (the Appendix B > attached to the Application is not the correct form). Please download and > complete Appendix B and forward this to the Committee. >

See attached.

> The first sentence of the information and consent form could benefit from

> rewording as "…investigates developing of a business planning …" sounds

> awkward.

See change to Information and Consent form.

Please confirm that these changes are appropriate. The translation will be sent when it has been completed. Probably by the end of next week.

cheers Deborah

15.2 Ethics Application 5201200767 – Final Approval

Faculty of Science Research Office <sci.ethics@mq.edu.au> Wed, Oct 24, 2012 at 11:12 AM

To: Prof Deborah Richards <deborah.richards@mq.edu.au> Cc: Prof Richie Howitt <richie.howitt@mq.edu.au>, Faculty of Science Research Office <sci.ethics@mq.edu.au>

Dear Dr Richards,

RE: Ethics Application Entitled: "Technology Usage of Farmers in Sri Lanka" Reference number: 5201200767

The Faculty of Science Human Research Ethics Sub-Committee has reviewed your application and granted final approval, effective 23rd October 2012. You may now commence your research.

This research meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). The National Statement is available at the following web site: http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf.

The following personnel are authorised to conduct this research:

Professor Deborah Richards Mrs Tamara Ginige

NB. STUDENTS: IT IS YOUR RESPONSIBILITY TO KEEP A COPY OF THIS APPROVAL EMAIL TO SUBMIT WITH YOUR THESIS.

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuingcompliance with the National Statement on Ethical Conduct in Human Research (2007).

2. Approval will be for a period of five (5) years subject to the provisionof annual reports.

Progress Report 1 Due: 23rd October 2013

Progress Report 2 Due: 23rd October 2014

Progress Report 3 Due: 23rd October 2015

Progress Report 4 Due: 23rd October 2016 Final Report Due: 23rd October 2017

NB. If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renewapproval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

4. All amendments to the project must be reviewed and approved by the

Committee before implementation. Please complete and submit a Request for

Amendment Form available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

5. Please notify the Committee immediately in the event of any adverseeffects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.

6. At all times you are responsible for the ethical conduct of yourresearch in accordance with the guidelines established by the University.

This information is available at the following websites: http://www.mq.edu.au/policy/

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy

If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have final approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.

If you need to provide a hard copy letter of Final Approval to an external organisation as evidence that you have Final Approval, please do not hesitate to contact the Ethics Secretariat at the address below.

Please retain a copy of this email as this is your official notification of final ethics approval.

Yours sincerely,

Richie Howitt, Chair

Faculty of Science Human Research Ethics Sub-Committee

Macquarie University

NSW 2109

15.3 Amendment Approved

Faculty of Science Research Office <sci.ethics@mq.edu.au> Mon, Sep 30, 2013 at 10:18 AM

To: Prof Deborah Richards <deborah.richards@mq.edu.au>, Mrs Tamara Ginige <tamara.ginige@students.mq.edu.au>

Cc: Prof Richie Howitt <richie.howitt@mq.edu.au>, Ms Katherine Wilson <katherine.wilson@mq.edu.au>

Dear Prof Richards,

RE: Ethics Application Entitled: "Technology Usage of Farmers in Sri Lanka". Reference number: 5201200767.

Thank you for your recent correspondence. The following amendment has been approved:

Adding A/Prof Michael Hitchens as Associate Investigator

Gathering additional information at 3 or 4 locations regarding farmers' expenses and suppliers.

Two additional points: As before, please list the local contact on the updated Information and Consent forms. Second, you may be aware of the University's updated policy regarding insurance covering research conducted outside of Australia. Please contact Maggie Feng for additional information as insurance decisions are made on a case by case basis.

Please do not hesitate to contact the Faculty of Science Research team at sci.ethics@mq.edu.au should you wish to discuss this matter further.

Regards

Faculty of Science Human Ethics Committee Secretariat

Professor Richard Howitt (Chair, Dept of Environment & Geography)

Katherine J. Wilson, Research Administrator

Faculty of Science

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