UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING & INFORMATICS

SMARTPHONES IN AGRICULTURAL RESEARCH MONITORING AND EVALUATION: CASE FOR SWEET POTATO VINES DISTRIBUTION

By

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A project report submitted in partial fulfillment of the requirement for the award of Masters of Science in Information Technology Management of the University of Nairobi.

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DECLARATION

This research project, as presented on this report, is my original work and to the best of my knowledge has not been presented for any other university award.

Luka Mwangi Wanjohi: ______________________ Date: ___________________________

(P54/65021/2013)

This project has been submitted as part of fulfillment of the requirements for the award of Masters of Science in Computer Science of the School of Computing and Informatics of the University of Nairobi, with my approval as the University Supervisor.

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DEDICATION

I would like to dedicate this study to all the Monitoring and Evaluation professionals who spend their time out in the field collecting invaluable data in the continent of Africa.

ABSTRACT

Data collection continues to be an integral part of the day to day practice of Monitoring and Evaluation in agricultural research. Data quality has a direct impact on the quality of a given M&E setup. For most projects however, there are always multiple needs competing for the same resources. This translates into various important components of a given project being less than optimally resourced, M&E included.

To overcome this handicap, researchers have been employing a number of ingenious ways to collect data for M&E with the use of minimal resources. The methods employed vary, and are informed by the research objectives. The use of ICTs in data collection for M&E functions is not new. This study evaluated the suitability of using Smartphones to collect M&E data for agricultural research.

A vine multiplication project for The International Potato Center was selected as a case for this research project. The project works with multiple vine multipliers who are supplied with disease free orange fleshed sweet potato vines for multiplication. These multiplied vines are then distributed to target beneficiaries.

A prototype based on Open data Kit was developed for this study. This app had three electronic data collection forms, modelled after paper based data collection tools which the project has used over time. A usability test with real world users was conducted. Users were exposed trained on how to use the prototype and then given time to test the application and give their feedback.

From the analysis of the results from the usability tests, the users are extremely impressed with the use of a smartphone based app for M&E data collection. They are impressed by the fact that smartphones are able to collect multiple data types and store the same in a single record e.g. form text, photos, location data, etc. they were however not receptive to the using smartphones when the data being entered is a lot because of the screen size.

LIST OF ABBREVIATIONS

ADP	Agricultural Development Project
CIP	Centro Internacional de la Papa, Spanish for The International Potato Center
ICT	Information Communication Technology
M&E	Monitoring and Evaluation
ODK	Open Data Kit
STATA	A general purpose statistical software package created by StataCorp.
USAID	United States Agency for International Development
VAD	Vitamin A Deficiency

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CHAPTER 1
INTRODUCTION

1.1 Background

Governments and major development agencies are increasingly turning to technology to support various Monitoring and Evaluation (M&E) efforts for their project implementations. The level of investment in M&E efforts is often directly proportional to the total investments available for the project. A development intervention linking agricultural research to health and nutrition provided a good platform for evaluating the use of smartphones for M&E in agricultural research. The intervention is using the nutritious orange fleshed sweet potato (OFSP) to combat malnutrition and Vitamin A Deficiency (VAD). This is being done by increasing the production and utilization of OFSP at the household level. Governments and development organizations are now working to provide quality sweet potato planting material to various households. Sweet potato reproduction is through vegetative means. Trusted vine multipliers in various countries are provided with disease free sweet potato vines for multiplication and distribution to households within their respective areas.

Monitoring is a continuous management function to ensure project implementations are on track. Evaluation is a systematic assessment of an ongoing or complete project to determine whether objectives are being met. An example of an M&E system in agricultural research is a system for recording the acreage of marketable maize produces per district and transmitting this data to researchers and program managers. Good M&E can make projects work better, assess impact, steer strategy, increase stakeholder ownership, build the capacity of stakeholders to hold programme financiers and implementers to account and share learning more widely. A good M&E system should provide an easy way to capture new data and disseminate the same to all the stakeholders.

A smartphone is a cellular phone that performs many of the functions of a computer, typically having a touchscreen interface, Internet access, and an operating system capable of running downloaded applications (Google Search). Most modern smartphones come with an embedded camera. The convergence of all these services on a single device makes for a great ICT tool to experiment M&E with.

Most traditional approaches to M&E in agricultural research are a mix of paper and Information Communication Technology (ICT) based systems. ICT provides us with tools for easy data collection, verification, analysis and dissemination of outputs. In paper based M&E systems, data is collected on paper forms and later entered into a computer program for analysis. The results are then disseminated to various stakeholders. More advanced ICT based M&E approaches employ electronic data collection methods using laptops, personal digital assistants (PDA's), cameras, etc. to collect data in the field. Electronic data collection improves the efficiency of data collection by speeding up the data entry process and minimizes data entry errors by employing real time data entry validation. The typical scenario for most agricultural research programs involves the principal researcher identifying the monitoring and evaluation needs. These are then used to inform the design process.

Considerations made by researchers in designing an appropriate M&E system include: budget, personnel, time, etc. Researchers always try to strike a balance between the cost associated with setting up an M&E system and the benefit derived from the system. An ideal scenario would be one where M&E data is captured and disseminated to stakeholders as soon as it is generated, with real time validation. This requires a tool that is capable of electronic data capture at source with a capability to transmit this data immediately. Smartphones are bridging that gap; they have the unique capability of providing researchers with an excellent additional M&E tool. What is more exciting is the fact that they are not only cheaper than traditional laptops and PDA's but they are also easier to handle because of their size and have multiple features all in one device.

1.2 Problem Statement

The study aimed to design and test a smartphone based M&E system for a vines distribution project in Nigeria. The vines distribution project was being implemented by the International Potato Center (CIP).

The delayed digitization of monitoring data, limited data capture and control options offered by traditional data capture methods and the subsequent delay in dissemination of this information and feedback to stakeholders is undesirable in today's fast paced world.

There is a need to provide stakeholders in any given project with a near real-time quality monitoring and evaluation system using affordable smartphone technology.

1.3 Research Objectives

The objectives of the research were:

1.) To establish the M&E process involved in management of sweet potato vine distributions
2.) To identify challenges faced by various stakeholders in the M&E process
3.) To design and develop a smartphone based M&E system that can address the challenges identified

1.4 Research Questions

- What are the M&E processes involved in a typical sweet potato vine distribution project?
- What are challenges posed by the current M&E setup?
- How can smartphones be used to improve the efficiency of M&E functions in agricultural research?
- What are the possible limitations and emerging issues of using smartphones in M&E for agricultural research?

1.5 Anticipated

The results of this study were mainly from the feasibility and usability tests of the smartphone based M&E system. The study documented and published all the processes, lessons and challenges of setting up and implementing the system. During the study there were frequent interactions with non-technical users. Some of them had never used smartphones before and this study anticipated to contributing to theory on developing of ICT solutions for non-technical audiences.

The expected outcome was a smartphone based application that can be used for M&E activities in sweet potato vine distribution. The smartphone based M&E system should improve efficiency by reducing data entry errors, reduce the time between data collection and data entry, improve evidence of monitoring data by use of new data types such as pictures and reduce overall on management overhead costs.

1.6 Significance of this Study

The significance of this study can be broken down into two:

Importance to the Information Technology Industry

Technology is as important as the work that it enables us to get done. We are living in a day and age when there are several new applications and hardware devices being released into the market every so often. These are released as either commercial products or as free products sometimes with the source code available for anyone who cares to develop the product further. Sadly not all of these applications are useful. Some will be duplicates of an existing solution; others will not be user friendly, while in some instances there are good products that will simply never get noticed. This study offers an opportunity to have a critical look at smart phones and their suitability in the M&E field. The study documented important feedback to the players in the ICT field who are developing smartphone based applications and hardware devices for M&E.

Importance to M&E

M&E is increasingly becoming an important aspect in the implementation of various agricultural research projects. M&E can only be useful if it answers the question; why has there been success or failure? Many donors recognize this and are rejecting activity reporting, instead asking for results and impact reporting, (Woodhill, 2007). The use of smartphones in M&E is expected to improve the quality of monitoring data capture, increase the speed of data entry and analysis and increase the speed of disseminating the results. Smartphones data collection offers three new data types which can be very useful for monitoring and evaluation: Geographic data, multimedia data and electronic sensors e.g. fingerprints, etc. All these are available in a single device. This study documented to what extent smartphones can add value to the way M&E is implemented in agricultural research programs.

Importance to sweet potato seed production monitoring

A lot of investment goes into the production of clean sweet potato planting material. If it were possible, farmers would receive sweet potato planting seed as tissue culture to avoid risk of disease contamination. This however is something the ordinary farmer would not be able to handle. The only other way is to deliver the seed to the farmer in the form of a plantlet, since sweet potato is clonally propagated. Research stations would never be in a position to produce enough plantlets to satisfy demand for sweet potato planting materials. This is why vine multipliers play such an important role in bridging the seed availability gap. Unfortunately, without close monitoring, clean seed handed down to a multiplier from a given research station can easily become contaminated. The plant has a short growing season, and thus a reliable monitoring system that enables transmission of feedback to relevant stakeholders about the growing vines in an almost near real time basis is required. The study documented to what extent smartphones can bridge the monitoring gaps for such an undertaking.

1.7 Assumptions

The study assumed that the use of smartphones, in particular Android based smartphones, is mostly intuitive. The use of Smartphones is now widespread worldwide. It was also assumed that there is reliable internet coverage either in the fields where the sweet potato vines are multiplied or at least in the neighboring towns.

CHAPTER 2
LITERATURE REVIEW

2.1 Traditional M & E Systems

Traditional M&E systems are designed and implemented to assess accomplishment of activities /tasks which relates to the "did they do it" question. The implementation approach focuses on monitoring and assessing how well a project, program, or policy is being executed, and it often links the implementation to a particular unit of responsibility. However, this approach does not provide policymakers, managers, and stakeholders with an understanding of the success or failure of that project, program, or policy. Results-based M&E systems are designed to address the "so what" question. A results-based system provides feedback on the actual outcomes and goals of interventions (Holzer, 2000). Beneficiaries of research projects are now demanding implementers of agricultural research projects be accountable for results, transparent, and to provide more efficient and effective services (Kusek and Rist, 2001; Kusek and Rist, 2004). Additionally, there are demands from various stakeholders to measure accurately the results of aid-financed development activities. Results-based M&E is a powerful management tool that can help different stakeholders or actors (e.g. normal user, policy makers and decision makers) to track progress and demonstrate the impact of a given project, program, or policy (Hendricks et al., 2008).

2.2 Monitoring and Evaluation Contrasted

In general terms, monitoring focuses on the day to day project management issues. Monitoring tries to assess whether activities are implemented effectively and efficiently (Olubode-Awosola et al, 2008). Evaluation addresses issues that are related to impact, relevancy and sustainability (Jaszczołt et al., 2008). Whereas monitoring will focus mostly on whether or not results were achieved as planned, evaluations will attempt to explain why and how such results were achieved or not achieved (Binnendijik, 1999). These two components are generally viewed as two distinct but complementary sources of performance information, which are necessary for effective result-based management.

A summary of the differences between monitoring and evaluation is available in Table 1: Differences between Monitoring and Evaluation, in the next page.

Table 1: Differences between Monitoring and Evaluation

	Monitoring	Evaluation
Timing	Continuous throughout the project	Periodic review at significant point in project progress – end of project, mid-point of project, change of phase
Scope	Day to day activities, outputs, indicators of progress and change	Assess overall delivery of outputs and progress towards objectives and goal
Main participants	Project staff, project users	External evaluators / facilitators, project users, project staff, donors
Process	Regular meetings, interviews, monthly, quarterly reviews, etc.	Extraordinary meetings, additional data collection exercises etc.
Written outputs	Regular reports and updates to project users, management and donors	Written report with recommendations for changes to project – presented in workshops to different stakeholders

Source: Fowler, A. (2013).

2.3 ICT in M&E

ICT can help projects' M&E by making the process faster while providing higher data quality with fewer staff. Rather than spend days or weeks manually transcribing data from paper surveys into a spreadsheet or database, mobile data collection tools enable direct transfer of data to central databases where data can be immediately analyzed and acted upon. Several mobile data collection tools are now available and work in both online and offline modes. This enables field workers to collect data in remote areas and then synchronize the data into a cloud database when they return to an area with connectivity. In online mode, when the mobile device is within range of a mobile phone signal or connected to the internet, that data can be automatically transmitted to the server (similar to how one can draft emails in Outlook when offline and send them later when online). As a result, data quality is improved because the transcription from paper surveys to an electronic data store is eliminated, significantly mitigating the opportunity for human errors in the data entry process. (USAID briefing paper, December 2012)

The mobile data entry forms offer numerous data validation options that can ensure that all required data is entered and that the data conforms to the correct formats and value ranges, again reducing the effort required to clean data. Periodic data audits may still be needed, such as against new users of the mobile app, and because people can still make typos and enter a response that is logically inconsistent with other responses. However, the data review effort becomes an occasional, instead of an ongoing, intensive activity. The trend with these tools is to store the data “in the cloud”—in a central database accessible from any internet- connected location. This makes the data more readily available to those who previously may have waited weeks or months for paper reports to be transcribed and summarized. Storing data in the cloud also makes the data more open and transparent, as it can be made accessible to stakeholders, from field workers to country and head office staff, governments, partners, and donors, all of whom may need the data for planning and decision-making.

Mobile tools also enable regular feedback and early insights that can be applied immediately for greater impact, whether to correct course or address emerging issues. Using these tools also allows timely data mining to monitor trends to inform program design and direction. Instead of traditional M&E efforts with intensive data collection and analytical periods, such as baseline and end of project analysis, the data can now be collected iteratively and continuously throughout the project. With the emergence of GIS technology and GPS-enabled mobile phones, this information can now be presented on a map as another method for gaining early insights and detecting trends that have a geographic basis. (Qiang et al, 2012)

Moreover, the use of a mobile application for monitoring and evaluation can pay dividends beyond a single project. Survey designs, data management processes, and data definitions and standards developed on one project can potentially be leveraged on other projects, reducing the need to reinvent the wheel on each project. (http://www.worldbank.org/en/topic/ict, retrieved March 2014)

ICTs, however, can still present challenges for implementation. There are constantly new mobile applications coming onto the market, which can make it difficult to know what the best fit is for your project needs. The mobile device sector is also highly competitive and therefore rapidly changing, from netbooks to mobile phones to tablets, and from Blackberry to Apple to Android mobile operating systems. It is also important to incorporate ICT into the budget, staffing plan, design, implementation, and management of M&E efforts at the beginning of the project. Doing so will likely increase the chances of successful ICT implementation.

Table 2: Summary of ICT technologies being employed in data collection

Application	Where	Description
Applied Data Logix and Octagon Data Systems Ltd	India and Kenya	These two partners have developed applications that use digital scales to collect data on farmers' yields at tea and dairy community aggregation centers in Kenya. Agricultural product is weighed on a digital scale, and then data uploaded to a central repository. The data is aggregated each month and the farmers are paid according to the records. Strength: Local support for tools available Weakness: Not open source; does not collect M&E all data types http://www.adl.co.in/ - http://www.octagon.co.ke
Cropster	Latin America	This application provides online tools for sustainable supply chains - including producers, traders and processors of agricultural products. It also has an M&E tool, enabling efficient data collection and exchange within producer groups and between producer groups and NGOs or commercial partners. This tool is not a classical M&E platform, where data is only available to the questionnaire managers, but also to the people who are providing their answers and valuable insights. The tool also combines data generated through commercial processes (production, quality, and price) with questionnaire data. Strengths: Strong tool for aggregating market and production data Weakness: Not open source http://www.cropster.org
Digital Purjee Information Service	Bangladesh	The Digital Purjee Information Service via SMS ensures timely harvest, enhanced income for farmers, and ready supply of raw materials for sugar mills. This project is a joint initiative between the UNDP-supported Access to Information Programme, organized by the Prime Minister's Office and the Bangladesh Sugar and Food Industries Corporation of the Ministry of Industries. Strength: Farmer support tool

		Weakness: Not open source; not a research M&E tool http://www.epurjii.info/en_index.php
Frontline SMS	global	Two versions of the software exist now. Version 2 has a more intuitive interface, smoother operability, and increased stability. However, because it was just launched, it is still lacking some of the more complex data analytical features of Version 1. FrontlineSMS is used in a variety of ways. In one instance, the application was used to organize messages on disease outbreaks, which lead to proper diagnosis. http://www.frontlinesms.com/
iFormBuilder	global	The software allows the user to filter the data, and is compatible with XLS, XML, JSON, ATOM and RSS. Real-time data visualization through live data feeds are possible through tools like Klipfolio, Gekoboard, RoamBI, and Google. Custom databases and dashboards can be created for entire organizations and/or companies (allowing multiple users to access the same central data hub and maintain agency/company standards). Integration with Google allows for custom analysis reporting and GIS representation. Strengths: Very strong in data collection building for M&E; Can integrate with multiple web services Weakness: Runs on iOS only. This is not a popular platform here in Africa. There are more Android devices than iOS devices available. This gives price a cost advantage http://www.iformbuilder.com/
mPower Social Enterprises Limited	Bangladesh India and the Middle East	mPower Social Enterprises Limited are working in Bangladesh, India and in the Middle East using mobile technology to get real-time information from the field. The application will be used to track the agricultural information, agri-markets, and monitor the growth of the seeds. It will also be used to implement a mobile-based public health module and track health of livestock animals. Frontline workers, using an Android mobile handset to ask the farmer questions on the health of their animals. The collected data is sent using EDGE/GPRS and a

		dashboard is created in the web for each individual beneficiary. The veterinarian can suggest or give instruction to the staff, who can then instruct the beneficiaries on a real-time basis. http://www.mpower-social.com/
Smartagro	Chile	SmartAgro is a smartphone application that allows farmers or agronomic experts to collect in real time data about the field (type of products, operations carried out on the field, use of inputs, quality of soil, inventory of tools and machines, pictures of diseases on the crop, etc.) onto a smartphone. The application is fairly easy to use for new technology users. Once collected, the data is uploaded onto a computer (which can be shared or personal). A web application allows NGOs, and public and private organizations to interact and advise the farmers based on the information collected. http://www.smartagro.net
Text to Change	Africa	This application creates simple surveys in the form of a quiz, keeping length under 160 characters. The end-users send and receive the text messages for free, and the Telecom provider bills the partner for messages sent and received. The data is collected continuously and can be accessed by a stakeholder in real-time through our platform that runs online. http://www.texttochange.org/

Source: e-Agriculture, 2012.

2.4 Mobile Data Collection Technologies

Figure 1 shows a generic illustration of the main components of a mobile data collection system:

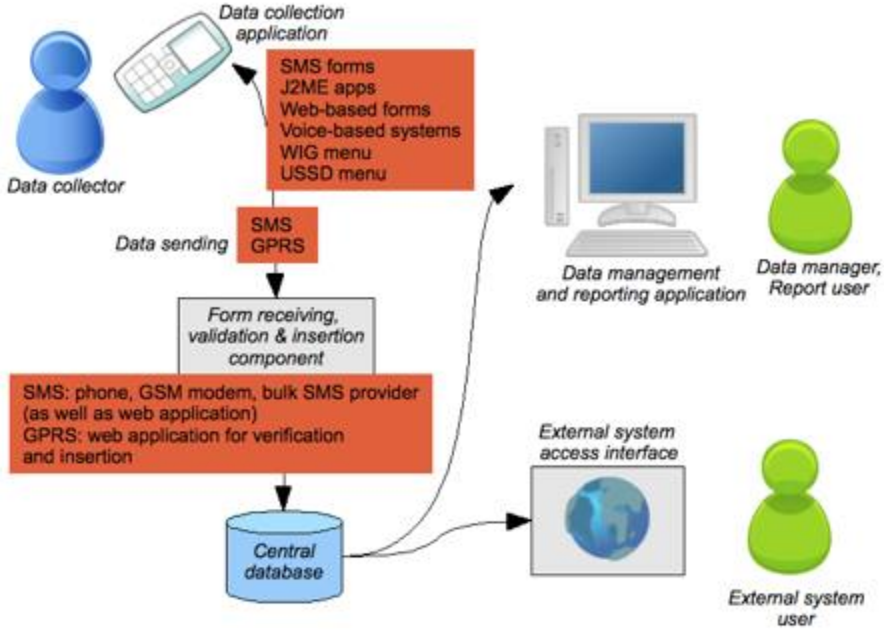

Figure 1: Mobile data collection technologies. Source: M. Loudon, mobileactive.org

The main components are:

- The data collection client interface, which the user interacts with to accomplish data collection and transmission
- The data transfer method, which dictates how the information input on the phone is transmitted to a central server for storage and retrieval.
- Server-side components to receive and store the data, and allow users to display and manage the database.

Table 3: Common mobile data collection techniques

Technique	Description
Short Message Services (SMS)	Most popular where user sends data in using inbuilt SMS functionality on the phone over a GSM network.
	Compatible with all mobile phones
Smart Applications (Apps)	rogramming language is used e.g. java and loaded on a phone that can support the application
	Usually developed for smart phones, and are platform specific.
Web-based forms	client uses phone's web browser to access the application. The user browses to a website, where the form is published in an optimized format
In voice-based	User dials a number and then chooses from options on a menu ("to record the answer to this question, press 1 for yes, 2 for no, etc).
	Useful when there are low levels of literacy among data collectors, or when a system is needed that caters for both landline and mobile
Unstructured Supplementary Service Data (USSD)	s is a real-time question-response service, where the user initiates a session and is then able to interact with the remote server by selecting
	e.g. *544# and following text responses via menus
	The main limitations of USSD is the requirement for a continuous connection during the session, a limited length of USSD menus, and expensive acquisition and licensing constraints in the Kenyan market

Smartphone based data collection tools

There are a good number of smartphone applications that enable you to collect monitoring data. These apps come with programmable interfaces that allow users to develop their monitoring tool, with varying degrees of complexity. The same apps also have interfaces allowing users to access their data after it has been collected, for analysis. Some of the major apps are listed in table 4.

Table 4: Mobile application development tools

	RapidSMS	**OpenXData**	**FrontlineSMS**	**Nokia Data Gathering**	**Open Data Kit**
Programming Language Required for Customization /Configuration	Python with Django	Java, Java ME	Java	Java, Java ME	XForms to generate Forms, Java to modify base code.
Developers	UNICEF and open source community	Open source community	Kiwanja	Nokia	Open Source Community. Notably University of Washington and supported by Google.

Source: https://docs.google.com/spreadsheets/d/1g_qDdnGGJFfLOcBDEVX7-lH8IS_m_MIVbG97lNM_UrA/edit?usp=sharing, retrieved March 2015

2.5 Use of Smartphones in M&E

Several studies have been conducted on the use of phones, both feature based and smart phones. A greater number of these studies have been in the health and agriculture sectors. There are excellent write-ups by the World Bank on general applications of mobile phones in monitoring and evaluation of agricultural research projects (Qiang et al, 2012). The website http://lindaraftree.com/ has been publishing on great stories and articles on M&E in a technology enabled world. It provides interesting perspectives on the topic of using phones for M&E especially because the author writes about experiences regarding projects implemented in Sub Saharan Africa (SSA).

Another study explores the use of smartphones by farmers, but the focus is on technology adoption (Ochieng, 2012). There is an excellent study that captures the use of smartphones as an M&E tool using ODK (Anokwa, 2009). The study however was carried out in the health sector by AMPATH in Eldoret, Kenya. This study focuses on the use of smartphones for M&E. Other studies have put in a lot of emphasis on use of ICT's for data collection and little is mentioned about data analysis and dissemination. This study will document the possible advantages and limitations that come with the use of smartphones for M&E during data analysis. It is still a difficult task for various ICT and data managers to successfully make a case for use of smartphones in M&E. This study hopes to build the broader evidence based on the use of ICT's in M&E with important feedback on how smartphones can be used for M&E in agricultural research.

2.6 Monitoring and Evaluation in Agricultural Research

During 2009, the Institute of Development Studies (IDS) and Keystone Accountability, with financial support from the Bill & Melinda Gates Foundation conducted an online survey to identify key priorities and challenges in current M&E (monitoring and evaluation) practice in agriculture. Two interesting findings from this survey were:

- M&E of agricultural projects is considered weak. Aspects of M&E that are viewed as particularly inadequate include the capacity of implementing agencies, incentives to invest resources in M&E within those agencies and in the wider field.
- Opinions are divided on the need for new tools and models, but in line with preferred M&E approaches there is an appetite for learning how to choose and use tools and methods that are sensitive to context, support multi-stakeholder perspectives and use new technologies intelligently

Over the past decade, development organizations have faced external pressure to become more effective, and many of them have launched agendas for results orientation. While monitoring and evaluation (M&E) is recognized to be a key element in understanding and effectively tracking and documenting the results of development interventions, it is also admitted that there is a general need to improve M&E in development work. M&E methods and guidelines have received much international attention, but the problems of putting M&E into practice and drawing lessons from field experience, have been less studied.

CHAPTER 3
METHODOLOGY

The method of choice for this study was case study. Research methods for this study are described in this section: The application of case study; why case study; the test strategy and anticipated outcomes.

3.1 Research Design

The approach adopted for this research was a case study. A sweetpotato vines multiplication project by CIP was identified as a suitable study case. The project involved multiplying disease free sweetpotato vines through select farmers. The multiplied vines would then be distributed to select households across six states in Nigeria.

3.2 Application of Case Study

To maximize richness and accuracy of data, as well as transferability of the findings, a case study was carried out on a sweet potato vine dissemination project in six different states in Nigeria. Case studies allow the researcher to become familiar with the data in its natural setting and fully appreciate the context (Punch, 2013).The International Potato Center has a sweet potato vine distribution project in Nigeria that aims to distribute clean planting vines to at least 1000 beneficiaries within a period of one year. The smartphone based M&E system was employed to track the process of growing the vines up to the distribution of the same. Previously, paper based tools have been used for M&E of such projects. These tools were: A form to register a vine multiplier; a form to register the field characteristics of each vine multiplier; a form for recording beneficiaries of vines when distribution of the same begins (see appendix A). Monitoring of the multipliers' fields is done by government of Nigeria extension officers known as Agricultural Development Project officers (ADP). These are trained agricultural personnel who offer technical backstopping services to farmers. Every state in Nigeria has one ADP officer.

Equivalent electronic forms were developed from the existing paper forms using a technology that can run on an Android based smartphone. The technology of choice was Open Data Kit (ODK). ODK is an open-source suite of tools that helps organizations author, field, and manage mobile data collection solutions. ODK has been developed by researchers at university of Washington computer science department. The electronic forms were loaded on 6 Android smartphones which were then handed to the respective ADP officer of each state. The ADP officers were trained on how to use the M&E tools before the start of the planting season. The six states were: Federal Capital Territory – Abuja, Kwara State, Benue State, Ebonyi State, Nasarawa State and Osun State

At the onset of the season, the ADP officers registered each vine multiplier contracted by CIP using the electronic registration form. This form collects among other standard sets of information the geographic coordinates of the vine multiplier. They also registered the details of the multiplier's field e.g. the size, the location, the expected output, etc. Every two to three weeks the ADP officers were expected to visit the vine multiplier's fields to check on progress and offer any technical assistance that may be necessary. These visits were recorded in the electronic monitoring form: date of visit, picture of the sweet potato crop progress in the field, any challenges being experienced by multiplier including a picture of the same, etc.

Once the vines being multiplied were ready for distribution, the vine multiplier would record details of the each beneficiary coming for vines on a sheet of paper. This paper would then be handed over to the ADP. The ADP would then digitize this data using an equivalent electronic ODK form on his smartphone. Distribution of vines could either be an ongoing activity where vine beneficiaries come for vines at the multiplier's farm or it could be a pre-publicized event at the local market or another public place e.g. church, school, etc.

All the data entered was stored in a secure database accessible over the internet. Transmission of the data was via cellular networks. All the Android phones were setup with a data only SIM card to restrict the usage of the smartphones to the M&E functions only. Nigeria has solid cellular network coverage, with all the State capitals throughout the country enjoying high speed 3G internet. The CIP M&E staff in charge of the project were granted access to the online database receiving data from the smartphones. Key learning points were documented throughout the process, and changes made to the original design to suit unaccounted for real life situations. One such change involved having the ADP officers scan the vine beneficiary records rather than typing them into the ODK form. The PDF's would then be uploaded onto a secure online server. This change was informed by the number of beneficiaries that were being recorded. They were too many to type all of their details comfortably using a smartphone. Throughout the whole season, limitations and strengths of this system were observed and documented. These were compared to the traditional paper based data collection.

3.3 Why Case study

1. The examination of the use of smartphones for M&E in agricultural research will be conducted within the context of their use
2. A case study will enable us to explain some real life situations with regard to smartphones for M&E in agricultural research which we are not able to capture through experimental or survey research. This is as a result of the detailed qualitative accounts often produced in case studies.
3. A case study can be used as a basis to apply solutions to situations.

3.4 Limitations of the case study

One of the main criticisms is that the data collected cannot necessarily be generalized to the wider population. Also, there tends to only be one experimenter collecting the data. This can lead to biasness in data collection, which can influence results more than in different designs. The study will try to document all results in as much detail as possible. This is helpful for any attempts to replicate successes that might come out of the study.

3.5 Data Collection Techniques

The following data collection techniques were used in the study:

Literature surveys: Relevant literature was reviewed on M&E, use of smartphones in M&E and literature relevant to sweet potato distribution.

Field visits: These were conducted to gain a general understanding of sweet potato vine distribution projects. They also provided an opportunity to know and interact with the various stakeholders.

Interviews: These included one on one and one to many interviews between the researcher and the various stakeholders. These were conducted where necessary to provide further clarifications on M&E processes and to refine workflows.

3.6 Data Analysis

The data gathered from the processes above is mainly qualitative and helped inform the design process. An inductive and deductive analysis approaches was adopted to develop from the data: M&E workflows, expected user experiences with smartphones, design and usability expectations, etc. The two approaches complement each other and offer the researcher a more complete understanding of the study at hand.

3.7 Evolutionary Prototyping Model

Prototyping is the rapid development of a system. The principal use is to help users and developers understand the requirements for the system. Users can experiment with a prototype to see how the system supports their work and the prototype can reveal errors and omissions in the requirements (Sommerville, I., 2000).

In this research project, an evolutionary prototyping model was adopted. The initial prototypes were produced and refined through a number of stages to the final system.

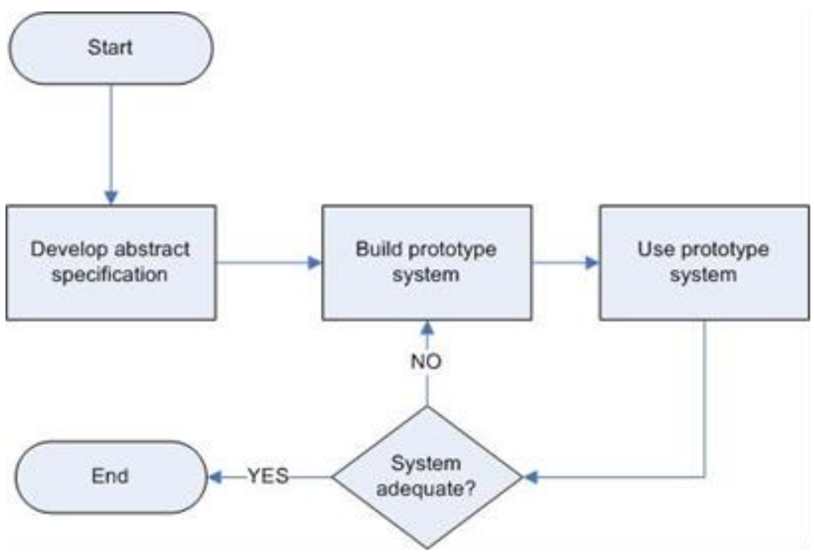

Figure 2: Evolutionary prototype. Source: Sommerville. I, 2000

The following are reasons for adopting evolutionary prototyping approach in the research project:

- To allow users to have an early interaction with the monitoring tool. This in turn enhances the likelihood of meeting user requirements and commitment.

- Allow accelerated delivery of a working monitoring tool.
- A prototype is likely to expose any misunderstandings between software users and developers
- A prototype will help detect missing and/or confusing services

CHAPTER 4
SYSTEM ANALYSIS AND DESIGN

4.1 System Analysis

The current M&E processes at the International Potato Center were analyzed. Information flows, users, and processes were identified. The focus was on the M&E system in place for vine multiplication which is analyzed in detail in this chapter.

Data Collection for M&E at the International Potato Center

This figure shows the general data collection workflows at CIP for various projects.

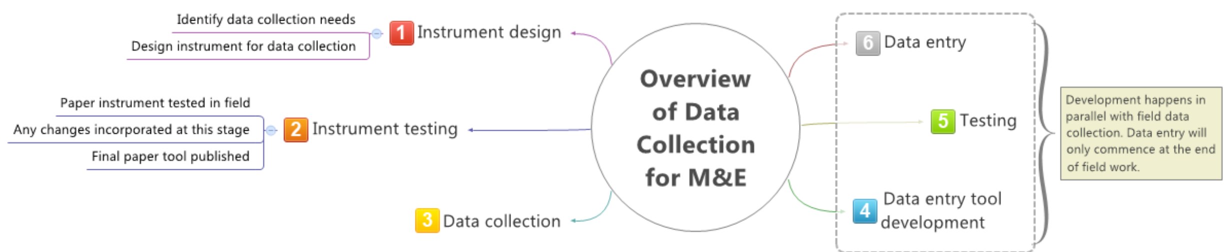

Figure 3: M&E Data Collection Overview at CIP

Most M&E functions are managed at the project level, with the head office having oversight roles only. Project managers are responsible for developing their own M&E plans, and will often decide on the most appropriate tools to use for their project given their M&E budget and needs. All projects however tend to have similar approaches to M&E data collection. All data collection is paper based. Data collection tools are developed at the project level in consultation with relevant colleagues across at the headquarters. Once the tool is ready, it is printed out and tested in the field. Any changes required will be noted during the testing process and these will be incorporated later. The tool will then be ready for actual data collection.

As field data collection is commencing, a data entry tool will be developed to digitize the data once it comes from the field. The choice of data entry software is left to the relevant M&E staff to decide. Mostly it will be the tool that the given member of staff is most comfortable with. For a few bigger projects, it is common to outsource the development of a data entry tool for your data entry work. The tool will be tested with real data coming from the field and should be ready by the time data entry is complete. Once field work is complete, data entry clerks will be hired and data will be digitized. This whole process can last for just a few days to several months, depending on the amount of data being collected. Larger surveys could last up to 6 months.

Review of current M&E system for sweet potato vines distribution

The current M&E system has been set up to achieve the following main objectives:

1. Maintain an in-country database of sweet potato vine multipliers
2. Support the monitoring of quality of sweet potato vines being produced by the multipliers

The primary responsibility of registering vine multipliers rests with the project manager. Sweet potato vine multipliers are recruited at the beginning of every planting season. A typical season for sweet potato lasts between 6 to 8 months. Vine multipliers are categorized into three tiers. The first tire multipliers are the ones who receive disease free planting material from either CIP or the national research institute e.g. the Kenya Agriculture and Livestock Research Organization. These multipliers have a contract with CIP to multiply sweet potato vines for distribution to second tier multipliers and farmers. The second tire multipliers have no contract with CIP and normally obtain their planting material from the first tire multipliers. The operations of the second tire multipliers are generally on a smaller scale compared to the first tire multipliers, and less formal as far as interactions with CIP go.

The project manager maintains a database of all the vine multipliers and updates this every year. The details captured for each multiplier include personal identification details, basic household and farm characteristics, geographic location coordinates of the multiplier's household and where possible a picture of the multiplier. This data is normally collected using paper forms which are then digitized and stored in either MS excel or MS word tables. The geographic location coordinates will be read and manually written onto the registration sheet. Any pictures taken will be stored in a folder and this will have to be manually linked to the registration data file. This registration process happens at the start of every planting season.

Once the season kicks off, CIP agronomists will normally visit the tier one multipliers at least once every two weeks. During these visits, they are supposed to provide any necessary technical support to these multipliers depending on the condition of the sweet potato vines. Every visit is logged using a standard paper form that contains key identification details of the vine multipliers land and the visiting agronomist. The agronomist makes a note of the condition of the sweet potato vines as at the given date, noting any positive or negative conditions and the assistance offered to the vine multiplier during the visit. This information will be taken back to the office and is used to inform any planning going forward. Sometimes CIP does not have enough agronomists on the ground and will rely on government employees from the relevant departments to carry out these type of visits and provide feedback.

4.2 Prototype Design

Table 5: Register sweet potato vine multipliers

Use case name	**A.1. Register sweet potato vine multipliers**
Use case description	Register vine multipliers at the start of every season.
Use case authors	Luka M Wanjohi
Actors	Project manager; M&E officer;
Locations	Vine multiplier field
Status	Identification of use case
Priority	1
Assumptions	Even though the actual registration is conducted by the M&E officer most of the times, the responsibility of this data rests with the project manager.
Primary pathway	Vine multiplier details registered on sheet of paper at multiplier's farm. This is done the M&E officer on behalf of the project manager.
Alternate pathways	Vine multiplier details registered on sheet of paper at multiplier's farm. The is done on behalf of the project manager by partner organizations working with CIP

Table 6: Digitize vine multiplier registration data

Use case name	**A.2. Digitize vine multiplier registration data**
Use case description	Digitize registration data for vine multipliers collected from the field.
Use case authors	Luka M Wanjohi

Actors	M&E officer;
Locations	CIP office
Status	Identification of use case
Primary pathway	Data collected from the field is delivered to the office for entry into MS excel or word by the M&E officer.
Alternate pathways	Partner organization digitizes data collected and sends soft copy of registration data to CIP.

Table 7: Monitor sweet potato vine multiplier field

Use case name	**B.1. Monitor sweet potato vine multiplier field**
Use case description	Monitor vine multiplier field every two weeks
Use case authors	Luka M Wanjohi
Actors	CIP Agronomist; Government staff; CIP partners;
Locations	Vine multiplier field
Status	Identification of use case
Assumptions	Activity carried out by a trained agronomist.
Primary pathway	Agronomist logs visit on paper form. This data includes: Details of multipliers; details of agronomist; purpose of visit; support offered during visit; status of sweet potato vines; estimate of amount of vines available; amount of vines distributed from the given plot in the last two weeks;
Alternate pathways	The above information is collected on behalf of CIP by a partner organization agronomists or a government agronomist for the given area.

Table 8: Digitize data collected from monitoring visit

Use case name	**B.2. Digitize data collected from monitoring visit**
Use case description	Digitization of data collected during monitoring visit
Use case authors	Luka M Wanjohi

Actors	M&E office; Agronomist
Locations	CIP office
Status	Identification of use case
Assumptions	This data was collected by an individual with formal training in agronomy
Primary pathway	Data collected is delivered to the office and digitized.
Alternate pathways	Partner organization of government employee who collected data digitizes it and sends a soft copy to the CIP office.

Table 9: Dissemination of monitoring information to stakeholders

Use case name	**C.1. Dissemination of monitoring information to stakeholders**
Use case description	Dissemination of monitoring information being collected to relevant stakeholders
Use case authors	Luka M Wanjohi
Actors	Project Manager; Project Stakeholders
Locations	CIP office
Status	Identification of use case
Assumptions	All data is digitized in a timely manner and correctly, for distribution to stakeholders.
Primary pathway	The project manager keeps all the project stakeholders updated on status of vine multipliers registration amount of vines available for distribution. Main stakeholders include: government officers, research management team at CIP, partner organizations, project donors, etc.
Alternate pathways	The information is disseminated by other CIP management

Table 10: Vine beneficiary registration

Use case name	**D.1. Vine beneficiary registration**
Use case description	Registration of sweet potato vines beneficiaries.

Use case authors	Luka M Wanjohi
Actors	Vine Multiplier; Vine Beneficiaries
Locations	Vine multiplier field
Status	Identification of use case
Primary pathway	The vine multiplier is provided with paper forms for recording details of every person obtaining sweet potato vines from their field. Details recorded include: names of beneficiary, age, sex, age of children living with beneficiary, name and amount of each sweet potato variety obtained from multiplier and the nature of the transaction.

Table 11: Digitization of vine beneficiaries' data

Use case name	**D.2. Digitization of vine beneficiaries data**
Use case description	Digitization of vines beneficiaries data
Use case authors	Luka M Wanjohi
Actors	M&E officer
Locations	CIP office
Status	Identification of use case
Primary pathway	The M&E officer will obtain all the vine beneficiary data from the various vine multipliers. This data is then digitized into MS excel or word documents.
Alternate pathways	Partner organizations or government staff collect and digitize this data on behalf of CIP.

Challenges identified with current monitoring system

1. It takes a long time between collecting data and having the data ready for dissemination due to number of factors:

   a. Data is being collected far away from the office and significant travel is required to obtain any data collected.
   b. Data is not immediately digitized to shortage of resources such as data entry clerks, data entry equipment, etc.
2. Risk of introducing errors into the data collected during data entry
3. There is little control into what is being entered into the paper forms by non CIP staff.
4. Different Data collected using different equipment: paper forms for text data, GPS device for the coordinates and a separate camera for the pictures. There is a risk of data mix-up.

The above system is expensive and error prone, and offers little assurance about the data quality.

4.3 User requirements

To address the above challenges, a new data collection system was proposed with the following requirements:

1. Field data entry to shorten the time it takes between data collection and data digitization
2. Electronic transmission of collected data from the field to the office
3. Electronic controls to check on quality of data being entered
4. Integrated storage of the different data types being collected: Text, GPS coordinates, pictures, etc.

Based on the above requirements, and taking into account affordability of proposed technology and geographical spread of the vine multipliers, a smartphone based solution to collect data was adopted.

Requirements for a smartphone based solution

Challenges identified with mobile phone based systems include:

1. Unlike desktop computers, mobile phones have lower processing and memory capacities. This means minimum processing function at the phone.
2. Mobile gadgets have small screen and keyboards making it unfriendly to use.
3. Cross platform compatibility issues for diverse models. Different versions have to be availed for mobile applications that are designed for installation.

4. Usability has to be keenly observed due to constraints in the size of the phone for installable mobile applications.
5. Network reliability of service providers may limit transmission of data between mobile gadgets and the backend systems at the head office.
6. Security of data is critical, and controls have to be put in place to ensure confidentiality, and authorized access, authentication, integrity of data, and non-repudiation.
7. Smartphones are highly popular and prone to misuse and theft.
8. Smartphones are not well adopted for prolonged use in field conditions. They tend to be prone to screen breakages, failure due to dust, etc.

To address the above challenges, the proposed prototype would:

1. Keep data to be collected at a minimum to ensure electronics forms are short and comfortable to fill from a mobile screen.
2. Develop a system that allows data to be collect without the need for the smartphone to be online at the time of data collection.
3. Invest in smartphones with modest screen sizes and processing capabilities.
4. Set up smartphone to be usable only for the functions of collecting data for M&E.

4.4 Design

This figure shows the overall mobile application. The system will replace the manual M&E system in place at the moment.

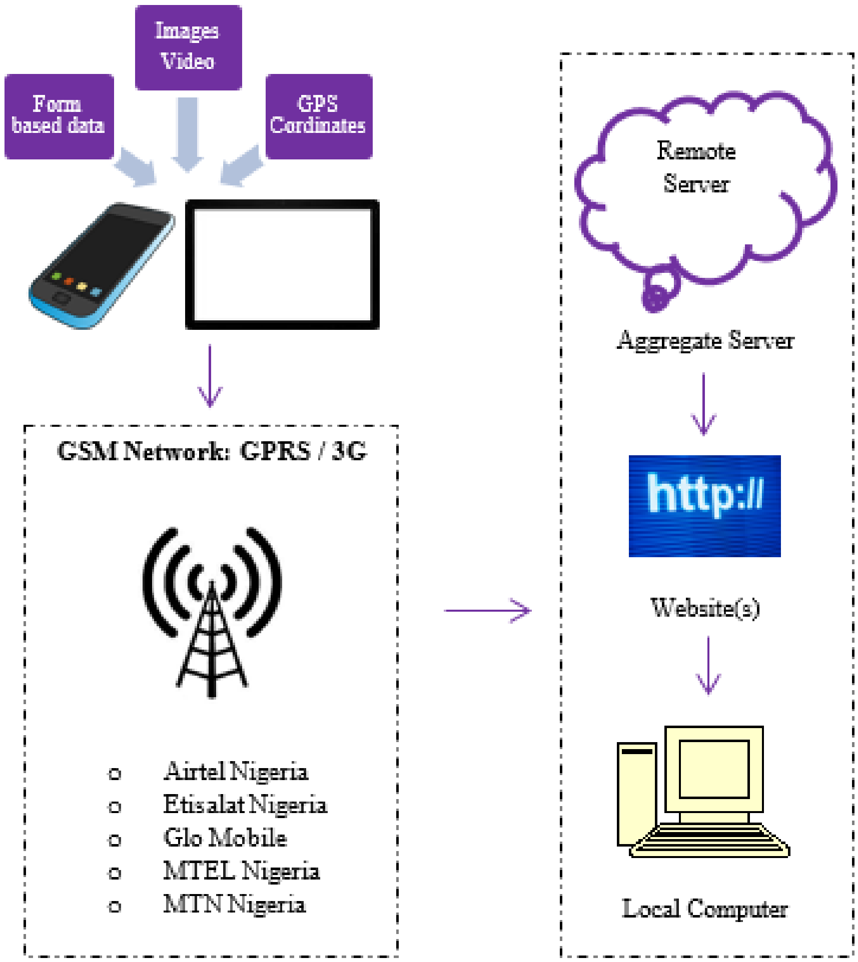

Figure 4: Smartphone based M&E system overview

Smartphone application (Mobile App)

The mobile app runs on the smartphones issued to the staff collecting data. This app has a user interface that allows form text data, GPS coordinates and photos to be taken and stored in one record with a unique identifier. This app is also responsible for ensuring that data is collected and stored on the phone irrespective of whether there is an active internet connection or not.

Hosted database and online information servers

A database server was set up to run online. This database is responsible for receiving the data being collected from the field by the smartphone application. The database was set up with a secure communication link between the smartphone application and the server. Only a properly configured client will be able to upload information. The database was also setup to allow privileged access for data download.

GSM network

Communication between the smartphone app and the database servers was through a high speed GSM network. A network with 3G capability is preferred since the data being transmitted includes medium resolution photos.

Revised M&E data collection system

The revised smartphone based system automates the collection and transmission of monitoring data electronically. Data collection forms are uploaded on the database server. To configure any smartphone for data collection, it is securely connected to the online server and the latest forms downloaded onto the phone. These are then used to run and data collected. The data collected is then sent to the server. Communication between the server and the smartphones is through the high speed GSM network. It is now possible for a project manager to have a quick overview of work going on a near real time basis as data is being uploaded onto the server as soon as it is collected and the GSM network is reliable.

Database design

The database tables have been modelled on the existing M&E system workflow. This will allow an easy integration of the new system into the existing structure.

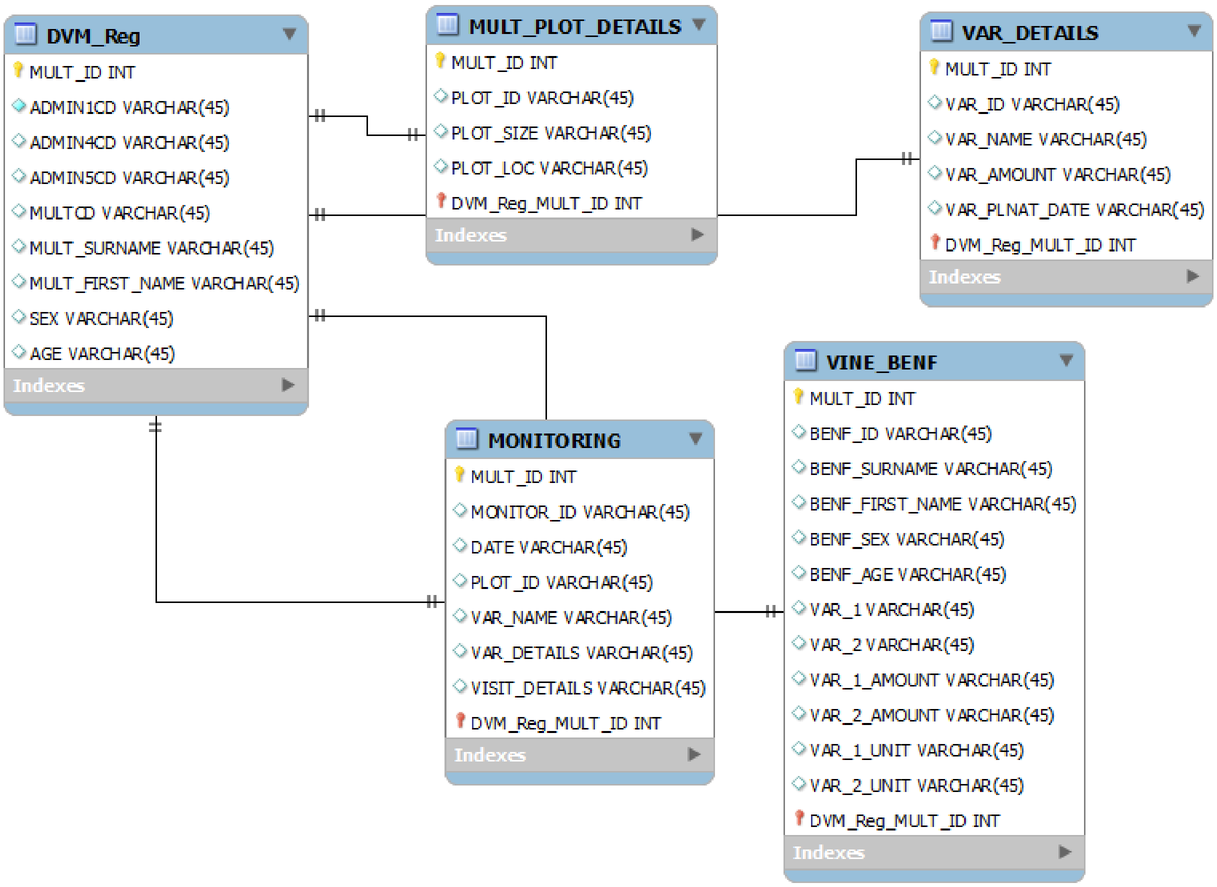

Figure 5: Database schema

User Interface design

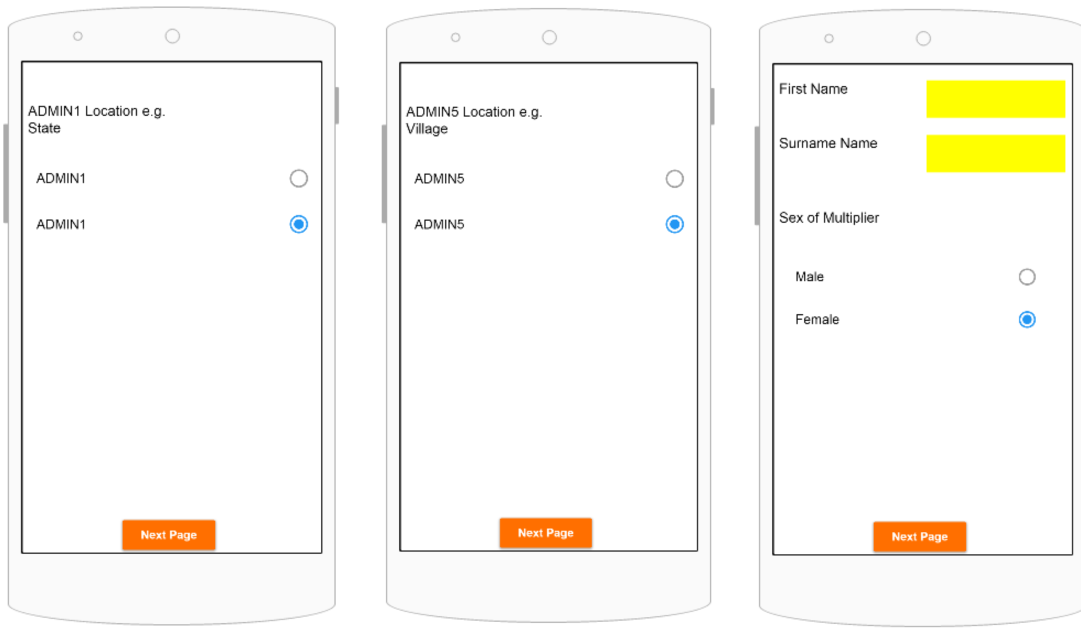

Figure 6: Design wireframes

User interface design impressions were created for the various forms. This was through wire framing. Wire framing allows one to produce design impressions depicting the desired user interfaces of a given application. The wire frames above depict some of the multiplier registration forms, running on an Android Nexus 5 device.

CHAPTER 5
PROTOTYPE IMPLEMENTATION

This chapter describes in details the implementation of the prototype. The different modules and supported technologies are discussed in detail, including choice of technology, coding, testing, and integration.

5.1 Choice of technologies used

Android

The mobile application is based on the Android platform that runs on smart phones. Android is a Linux-based operating system for mobile devices such as smart phones and tablet computers. The Android software stack includes an operating system, middleware and key applications. The monitoring data collection app runs on the Android operating system (OS). By providing an open development platform, Android offers the ability to build rich and innovative applications.

Android allows developers take advantage of the device hardware, access location information, run background services, and others since they have full access to the same framework APIs used by the core applications. The application architecture is designed to simplify the reuse of components (deloper.Android.com, retrieved May 2012). In addition, trends show that Android phones keep dropping in prices, making it an attractive hardware choice.

Open Data Kit

The data collection templates were developed using the Open Data Kit (ODK) toolset, another open source project by the University of Washington and Google. ODK allows rapid development and hosting of data entry forms. ODK handles the communication between the server and the smartphone to:

1. Maintain updated data collection forms for download by clients. Updated data collection templates are uploaded on the ODK server, called ODK aggregate. These are then available for download by the smartphone client. The ODK smartphone client is known as ODK Collect.
2. Receive the data being collected by ODK collect.

ODK does this automatically and there is very little effort require to setup this communication, once you have set up the ODK aggregate server properly. A single ODK server can host multiple ODK collect forms. ODK is an open source technology, meaning the whole suite of ODK tools is available at no cost. However, setting up the server requires specialized expertise and a reliable internet connection. For the sake of this study, a live ODK aggregate server was made available for use at no cost, by the International Livestock Research Institute (ILRI). ILRI is a sister research institute to CIP through the CGIAR consortium.

XLSForm

XLSForm is a form standard created to help simplify the authoring of forms in Excel. Authoring is done in a human readable format using a familiar tool that almost everyone knows - Excel. XLSForms provide a practical standard for sharing and collaborating on authoring forms. They are simple to get started with but allow for the authoring of complex forms by someone familiar with the syntax.

The XLSForm is then converted to an XForm, a popular open form standard that allows one to author a form with complex functionality like skip logic in a consistent way across a number of web and mobile data collection platforms. XLSForms are compatible with the subset of XForm functionality supported by Javarosa Project. XLSForms are supported by a number of popular data collection platforms, including ODK above.

Detailed effort has gone into developing the XLSForm's used in this study. The form logic is responsible for making sure that all the junk is not uploaded onto the server, irrespective of the level of computer literacy of the person collecting the data. These forms will be reused to setup a similar smartphone based monitoring system in all countries where CIP is working. These secondary users may not necessarily be very knowledgeable in computer programming. They should however be able to replace parts of the form with their country specific information, for example location information, without breaking the form logic.

The form logic is inbuilt into the form and provides important checks such as:

1. Specifying the upper and lower limits of allowable values per field
2. Performing dynamic calculations based on entered data to verify correctness

3. Implementing skips based on user input. This ensures unnecessary data is not collected and save time.
4. Verifying that an input whose length is known is entered as expected. For example a cell phone number in Kenya is always 10 digits long. The XLSForm logic verifies this.
5. Displaying smart choices to the people filling in the form where questions are being completed from a list of choices. Smart choices are selected based on previous user input
6. Specifying mandatory fields

MySql database server

MySQL is a relational database management system (RDBMS) that runs as a server providing multi-user access to a number of databases, and distributed under the open source and proprietary licenses. The Mysql database is used to hold data for long term storage once it has been downloaded from the online server.

Scripts

A script is a program written for a special run-time environment that can interpret (rather than compile) and automate the execution of tasks that could alternatively be executed one-by-one by a human operator. A STATA script was written to help manage data being downloaded from the online server. Most researchers within the organization are comfortable working with STATA. To improve user acceptance of the proposed system, a STATA script will be developed that can be used by the researchers to read the data collected using the smartphones into STATA data files.

5.2 Prototype development

Smartphone ODK Application

Below are screen shots of the electronic data collection forms implemented. Three M&E instruments were implemented in the prototype application: Vine Multiplier Registration Form, Vine Multiplier Monitoring Form and Vine Beneficiary Registration Form.

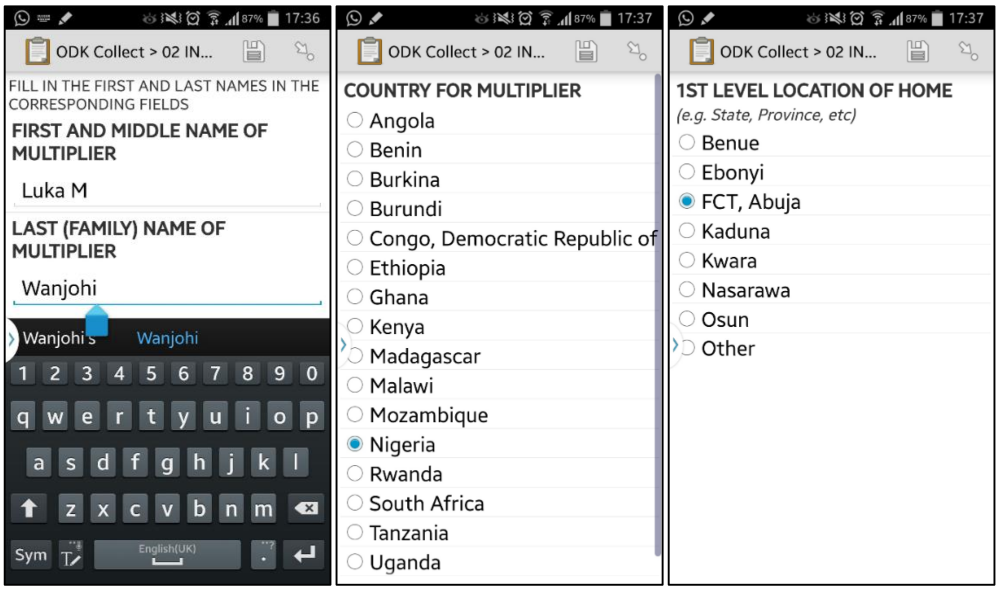

Figure 7: Screen shots of multiplier registration

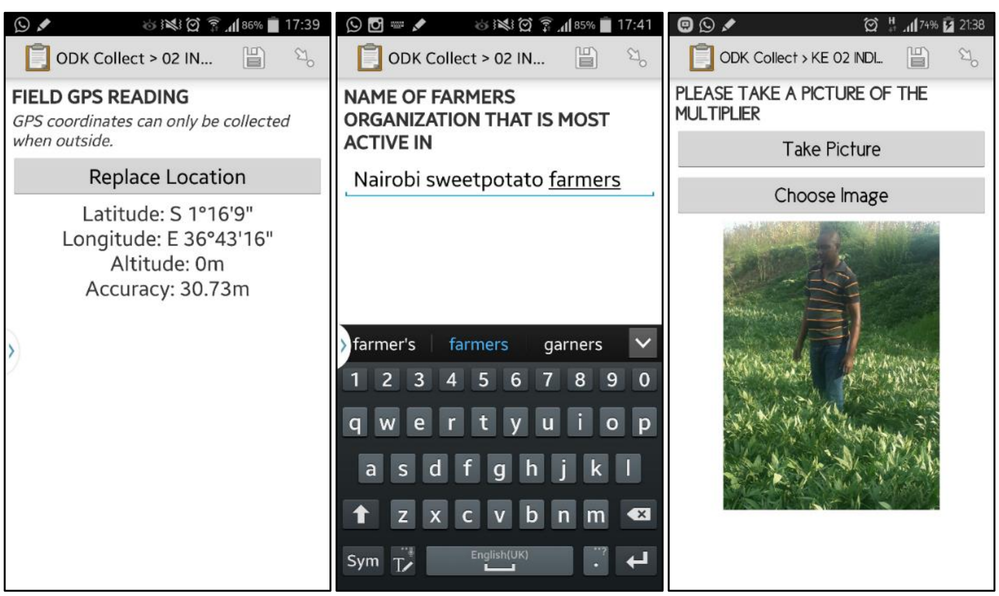

Figure 8: Different data types being captured and stored in a single record

select_one COUNTRY_LIST	COUNTRY	COUNTRY FOR MULTIPLIER	
select_one ADMIN1CD_LIST	ADMIN1CD	1ST LEVEL LOCATION OF HOME	((COUNTRY=${COUNTRY}) or (COUNTRY=99))
text	ADMIN1CD_OTHER	SPECIFY OTHER 1ST LOCATION OF HOME	
select_one ADMIN4CD_LIST	ADMIN4CD	2ND LEVEL LOCATION OF HOME	((ADMIN1CD=${ADMIN1CD}) or (ADMIN1CD=1999))
text	ADMIN4CD_OTHER	SPECIFY OTHER 2ND LOCATION OF HOME	
select_one ADMIN5CD_LIST	ADMIN5CD	3RD LEVEL LOCATION OF HOME	((ADMIN4CD=${ADMIN4CD}) or (ADMIN4CD=4999))
text	ADMIN5CD_OTHER	SPECIFY OTHER 3RD LOCATION OF HOME	
select_one MULTCD_LIST	MULTCD	MULTIPLIER	((ADMIN5CD=${ADMIN5CD}) or (ADMIN5CD=5999))

Figure 9: XLSFORM logic

Admin location choices filters to show only location belonging to a the larger administrative area selected in the previous response

CELL PHONE NUMBER (OWN OR NEAREST)		11 digits phone number e.g. 08xx xxx xxxx)	regex(.,'^[:digit:]{11}$')
FIELD GPS READING			
SEX OF DVM			
AGE IN YEARS		(0 - 99 yea	regex(.,'^[:digit:]{2}$')
YEAR STARTED MULTIPLYING SWEETPOTATO AS DVM			
MONTH STARTED MULTIPLYING SWEETPOTATO AS DVM			
YEARS OF EXPERIENCE GROWING SWEETPOTATO		(0 - 99 yea	. <= 99
NUMBER OF HECTARES ON FARM		(Overall for all crops in Hectares)	
NUMBER OF HECTARES IN LOWLANDS/VALLEY BOTTOMS		(Overall for all crops in Hectares)	
CATEGORY OF FARMER			
MOST PROFITABLE CROP			

Figure 10: XLSFORM logic

This checks to ensure that age of multiplier is not more than 99 years

Android hardware selection

This stud considered two Android devices for evaluation: One with a normal screen size like a phone and another one with a 7” screen (tablet).

Server Setup

For the purposes of this study, a server was made available for use at no cost by a CGIAR research program hosted by the International Livestock Research Institute at Uthiru, Kenya. There was no server setup or configuration required.

5.3 Prototype evaluation

A pilot test for the application was conducted at the CIP offices in Uthiru, Kenya. This was done in preparation for the usability test sessions. The objective of the pilot test was to:

1.) Test the equipment
2.) Provide practice on facilitation and note-taking
3.) Get a good sense whether test questions and scenarios will be clear to the participants
4.) Make any last minute adjustments

The usability test was then set up, with participants drawn from a pool of the intended users of the system. This was conducted in Nigeria and participants consisted of the CIP project manager in Nigeria, CIP agronomist in Nigeria and a number of government agricultural extension officers from 6 different states in Nigeria. The government extension officers would be the ones to collect most of the data since they are always visiting farmers in their respective states.

The test team had the below characteristics:

Audience Type

Project manager (CIP)	1
Agronomist	1
Ag extension	6
TOTAL (participants)	**8**

Computer Usage

0 to 10 hrs. wk.	5
11 to 25 hrs. wk.	1
26+ hrs. wk.	2
TOTAL (participants)	**8**

Age

18-25	0
26-39	3
40-59	5
60-74	0
TOTAL (participants)	**8**

Gender

Women	3
Men	5
TOTAL (participants)	**8**

The test team was assembled at the CIP office in Abuja for two days and each randomly issued with an Android tablet. The tablets were five LG nexus Android phones and three Lenovo 7" tablets. These had been preconfigured with the smartphone application and each setup with a 3G sim card from ETISALAT network.

The objective of the usability test session was to:

1.) Assess if participants are able to complete electronic data collection successfully
2.) Identify how long it takes to complete specified tasks
3.) Find out how satisfied participants are with the smartphone application
4.) Identify changes required to improve user performance and satisfaction

Test process

The test sessions were divided into three, each session lasting half a day and covering one of the three monitoring tools. Users would be taken through the electronic form at the start of each session, then they would take turns to interview each other while using the electronic forms to collect data. At the end of the session everyone would upload the data they have collected to the server. This would be followed by a short group discussion to review the given session. The facilitator took notes throughout all the sessions on:

1.) Task completion
2.) Any verbal feedback from the users
3.) Satisfaction ratings at the end of each session and overall satisfaction at the end of the last session.

Table 12: Task completion results

	Multiplier Registration Form	Multiplier Monitoring Form	Beneficiary Registration Form
Number of participants	8	8	0
Percent successful	100%	100%	0%

Table 13: Multiplier Registration Form

Findings	**Recommendations**
6 participants completed the task with ease (score of “2”) 2 participants needed prompting or had significant difficult completing the task (score of “1”)	The 2 participants found it difficult using a touch screen user interface. It was the first time they were using a touch screen interface.

Table 14: Summary on verbal responses and satisfaction ratings on the Multiplier Registration Form

Questions	**Responses**
What is your overall impression of the multiplier registration form?	Most participants felt the form was easy to use. They also liked the idea of being able to use a smartphone to do their work. This included the two participants who struggled with the form
What did you like best about the multiplier registration form?	No more carrying papers to the field 2) The ability to use the smartphones to take pictures as they visit farmers, even if not for CIP’s monitoring work, but for their reports generally.
What did you like least about the multiplier registration form?	No way to retain data on phone once it is sent to the aggregate server. This is an ODK inherent feature at the moment and it is impossible to change
Is there anything that you feel is missing on this application?	Two participants thought a keyboard is missing. They however felt confident that their typing

	rate would improve with continuous use of the system.
Do you have any other final comments or questions?	Overall everyone was very impressed at the ability to be able to carry out a registration of vine multipliers electronically, given that they have used paper registration for a long time.

Table 15: Multiplier Monitoring Form

Findings	**Recommendations**
6 participants completed the task with ease (score of "2") 2 participants needed prompting or had significant difficult completing the task (score of "1")	The 2 participants found it difficult using a touch screen user interface. It was the first time they were using a touch screen interface.

Table 16: Summary on verbal responses and satisfaction ratings on the Multiplier Monitoring Form

Questions	**Responses**
What is your overall impression of the multiplier monitoring form?	Easy to fill; well-structured and comprehensive; previous monitoring instrument described as haphazard because of nature of data being collected.
What did you like best about the multiplier monitoring form?	No more data entry in the office
What did you like least about the multiplier monitoring form?	No way to retain data on phone once it is sent once it sent to ODK aggregate.
Is there anything that you feel is missing on this application?	Two participants thought a keyboard is missing.
Do you have any other final comments or questions?	This particular form got everyone excited. The project manager and agronomist because they will be able to receive frequent updates about the performance of multiplier fields unlike before; and the fact that the data

	can actually confirm if the field staff actually visited the farmer or not from the system time stamps and GPS coordinates. The extension officers were fascinated by the fact that the system is monitoring their work, in addition to monitoring quality in the field.

Table 17: Beneficiary Registration Form

Findings	**Recommendations**
0 participants completed the task with ease (score of "2") 0 participants needed prompting or had significant difficult completing the task (score of "1")	None of the participants were able to complete the form in time since there were so many details to be recorded on a very tiny screen. It is best to continue recording this information by hand and sending the physical forms to the office. The smartphones could be used for scanning the physical forms which is an easier way to send the form.

Table 18: Summary on verbal responses and satisfaction ratings on the Beneficiary Registration Form

Questions	**Responses**
What is your overall impression of the beneficiary registration form?	Very difficult to complete on a tiny screen. The form is a replica of the physical form where approximately 30 beneficiaries are recorded per one A4 sheet of paper. This proved to be too tedious to digitize using the smartphone.
What did you like best about the beneficiary registration form?	The idea is good but it is best done using a computer not a computer
What did you like least about the beneficiary registration form?	Beneficiary form impossible to fill on small screen
Do you have any other final comments or questions?	A recommendation was made to have the extension officers collect physical sheets which have been completed with the beneficiary information, and scan them using smartphones and send them to CIP via email. This suggestion was well received and is worth trying.

Table 19: Overall summary on verbal responses and satisfaction ratings

Questions	**Responses**
What is your overall impression of the electronic data collection forms?	Participants like being able to record the details, GPS coordinates and a picture of a multiplier all in one record. They idea of using a smartphone to record monitoring data seemed to get everyone excited and eager to go out to the field to try out the tool on their own.
What did you like best about the electronic forms?	No more data entry in the office. The extension officers would be required to write a formal report every month about their field activities. This will reduce since a status report is being submitted during every visit.
What did you like least about the electronic forms?	Beneficiary form impossible to fill on small screen No way to retain data on phone once it is sent Project manager and CIP agronomist would not happy with collected data being downloadable only in excel. They would prefer working with STATA.
Is there anything that you feel is missing on this application?	Participants were eager to know how easy it is to develop another form if there was a need for a different form, including for their own work outside CIP.
Do you have any other final comments or questions?	The project manager and the agronomist impressed on the need to being able to use the downloaded data with ease in STATA. At the time of the test data would only be downloaded into an excel sheet from the ODK aggregate server. A STATA script was required to help them convert this data quickly into STATA to be able to get their buy-in into the new system. Participants were worried that internet speeds will not be as fast in the farmer fields as it were in the CIP Abuja office. The system is able to collect data even without an active data connection and data upload should only be done from the respective state capitals. All extension officers have their offices in their respective State capital, where ETISALAT GSM network is always on 3G.

Table 20: Summary observations on choice of hardware

	Smart Phone (LG Nexus 5)	**Tablet (7” Lenovo/Samsung/ASUS)**
Cost	Approx. cost currently USD 400	Approx. USD 300. The tablet is cheaper though only recently with the introduction of the 7” tablets.
Ruggedness	Same as the tablet. Both cannot withstand extreme weather conditions and heavy impact.	Same as the smart phone. Both cannot withstand extreme weather conditions and heavy impact.
Ease of use	Small screen makes use of smart phone ideal for very short surveys where most of the questions are closed-ended. They have been ideal for our monitoring with only a limited set of questions.	A bigger screen increases data entry accuracy since typing is more comfortable than on the smaller smart phones. This makes them ideal for use in bigger surveys e.g. baselines, etc
Handling	Smart phone easy to carry around predisposing it to misuse, increased risk of loss, etc	Tablet size makes it difficult to carry around and less likely to be personalized or misused.
Battery life	Same as the tablet. Both can be recharged using a mobile power bank	Same as the smart phone. Both can be recharged using a mobile power bank
Data transmission	Both tablet and smartphones offer similar options: 3G/Mobile data, WIFI, SD Cards, etc	Both tablet and smart phones offer similar options: 3G/Mobile data, WIFI, SD Cards, etc
Platform	Both support Android (Open Data Kit)	Both support Android (Open Data Kit)

CHAPTER 6
CONCLUSION

6.1 Achievements

This study has been able to achieve the following objectives:

Objective 1: *Establish the M&E process involved in management of sweet potato vine distributions*

A combination of field visits, phone interviews, email inquiries and reading published materials was employed in establishing the processes employed in managing M&E for sweet potato vines distribution activities. The various actors and their complete roles have been documented by this study. These activities also provided a soft entry for getting buy-in for the proposed smartphone based system amongst the key players. The M&E system is well mapped out and documented in chapter 4.

Objective 2: *Identify challenges faced by various stakeholders in the M&E process*

The following challenges were identified as facing the various stakeholders in the management of M&E for sweet potato vines distributions

i. Paper based data collection takes a long time before data being collected is digitized and used to provide any meaningful feedback to management.
ii. Important M&E data sometimes never gets to achieve its intended purpose as papers can get lost or they never get to be digitized. This has happened several times because data is being collected by extension officers who in turn have to arrange for transmission of the same data to the CIP offices. In between the logistics of sending over the data some of the papers get destroyed or they get lost.
iii. Errors introduced in between collecting data and digitizing it. This can be caused by the data being digitized by a different person from the one who originally collected it, especially if the handwriting is poor.
iv. In the paper based system, different data types are stored in different devices: Photos on the camera, GPS coordinates on the GPS devices and data on paper. Aggregating all the different data does not always happen in a timely manner and when it happens

it could be with errors. For example a photograph is matched with the wrong record, etc.

v. Management of geographic location data is a challenge to many people who have no formal training in the subject. Most staff normally read the GPS coordinates from the device and manually write it down on the sheet with the multiplier names. Sometimes they will omit to indicate whether a given GPS reading is in the south or west; other times it is a confusion as to which system to use with one multiplier being registered using degree decimals, another one registered using degree minutes and yet another one registered using degree minutes seconds. This increases the amount of data cleaning required before such data is of any use.

vi. Handling dates is a challenge especially when you are working across different countries and cultures. It is not always that people stick to the same convention of reporting e.g. DDMMYYYY for day/month/year respectively. There is always a high risk of using the day and month interchangeably, resulting in bad data.

vii. The old system was open to fraud. There was no way of ensuring that the extension officers are actually visiting the multipliers, since they could file reports from the comfort of their desks and send them in without conducting actual visits.

Objective 3: *Design and develop a smartphone based M&E system that can address the challenges identified*

A smartphone based solution for M&E data collection has been developed to address the above challenges. A pilot test was done at CIP regional headquarters in Nairobi, and an extensive usability test done in Abuja, Nigeria. Users were exposed to the solution for two days and allowed extensive use on their own. Data on task completion was recorded. Extensive verbal feedback from the users was collected and so were satisfaction ratings. A second usability test was conducted with CIP researchers in Nairobi on importation of the data collected using the smartphone system into STATA. From the results of the usability tests, it is clear that the solution is long overdue as far as M&E data collection goes for sweet potato multiplication. Challenges immediately addressed by the smartphone based solution include:

1.) Cuts down the lead time between data collection and digitization for analysis, significantly.

2.) Improved data quality checks, inbuilt into the electronic forms.
3.) Integrated storage of different data types: form text; GPS; photos; etc.
4.) Provides a good platform for enforcing standardized data management practices e.g. consistency on the way to report dates, GPS data, etc.
5.) Easy to replicate system across all countries where CIP is working, with data collected being easily comparable.
6.) Eliminates errors traditionally introduced in between data collection and data entry.

6.2 Limitations and Challenges

A smartphone based solution is great tool for collecting monitoring data that is typically short (1 – 2 A4 pages of questions). Beyond that usability drops significantly. This is because users find it tedious typing on the small screen whereas they can do the same task at a faster rate using a computer. For this reason the vine beneficiary registration form proved not usable.

Extensive testing must be conducted before going out to the field to collect data. This is because once users are in the field there is very little time available for fixing bugs. Going with a poorly tested application could prove extremely disastrous and expensive if your users cannot work because of a bug that was not caught during testing.

Users must be thoroughly trained on the use of smartphones before being allowed to go out in the field alone. Training must be hands one, in environments as close as possible to their day to day working environment when collecting this data. Data quality during training must be checked and only when it is satisfactory should they be allowed to go to the field. This is because, unlike paper, this electronic solution does not provide a fall back. Different users ten to have different backgrounds too, and this must be accommodated in the training design.

Smartphones are easy to loose, and prone to misuse. During this study, measures put in place to handle this included: Careful recruitment of your field staff; enable administrative control on Android to control installation and usage of non-work related apps; having data SIM cards only to avoid the devices from being used as telephones, etc.

There were challenges related to the data collection platform selected, ODK. After data is uploaded to the server by your field staff, it can only be downloaded as an MS excel file. Most researchers are used to data entry platforms providing options for data mobility amongst statistical packages such as STATA, SAS, R, etc. Within CIP the standard is to use STATA for data analysis. The excel file is only usable in STATA only if the data dictionary can be recreated in STATA. To address this challenge in this study a custom STATA script was developed that researchers can use to import the excel file into STATA.

The other ODK related challenge is the fact that running any server is never a mean task, let alone an ODK server. The costs of keeping a server online may outweigh the benefit of electronic data collection. Luckily there are a number of free servers available online. One must however choose carefully, as several of these options are variants of the core ODK system. Some of the issues to look out for include: How to they handle data post entry; how are multiple occurring records handled; what is their downtime rate; etc.

6.3 Conclusion

This study identified a need in M&E in agricultural research and developed and evaluated the suitability of a solution based on a trending technology. From the results, the solution has great potential to solve some basic data collection problems around data quality assurance and turnaround times. The results have also made the limits of the solution clear.

If adopted, this a great solution that will enable CIP to enforce uniform data quality checks across all the countries the organization is working in. The solution was tested in Nigeria and Kenya and can be easily replicated to suit any country CIP is working in by changing the relevant location information on the forms. It will cut down significantly on amounts of money spent on M&E through reduced data collection and management costs. Better informed project management teams through the availability of timely monitoring data should also be more efficient and effective.

The usability testing exposed a major challenge with digitization of bulky datasets using the smartphone application. This was mainly because of the amount of time it took to enter this data on a small smartphone screen as opposed to using a normal computer. The other challenge was related to the particular test setup. Recording beneficiaries' data is done under strenuous conditions: The vine beneficiaries queue up and their details are recorded before they can proceed to pick up their vines. This process has to be as fast as possible given that at any given time there are many beneficiaries turning up for vines and they would like the process to be as quick as possible. A stop gap measure to address this challenge has been to continue recording this information on paper forms. At the end of the exercise all the paper forms are then scanned using the smartphone and uploaded onto an online server. This is still better than having to wait for the forms to be physically sent to our offices. Smartphones have come up with capabilities to produce high quality scans. In this study, we tested the use of a free application called CamScanner to scan a sample beneficiary form and reprinted the scan. The quality was satisfactory for data entry in the office.

A possible solution in the future to rapid data capture and digitization of the beneficiaries' data would be through the use of Optical Character Recognition. This would enable the officers in the field to continue recording this data by hand as they are used to, and at the same time it would be easy to digitize this information rapidly thanks to the OCR technology.

6.4 Suggested Further Research

Mobile technology has been with us for a while now, and business applications on mobile continue to get better. M&E should not be left behind. With ODK being one of the leading open source platforms for mobile data collection, research efforts need to be directed towards improving data mobility across statistical packages for analysis after data collection.

A common challenge with most open source products is the lack of common standards to provide a common benchmark for products being developed. Immediate research work should go into development of standards for mobile data collection systems. This will provide a benchmark upon which mobile solutions for data collection should be evaluated upon. As an example, there is already an open source Stata module to import ODK data (White, 2014). This is an excellent tool needs to be enhanced to support a wide range of statistical packages.

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APPENDIX A: AUTHORITY LETTER

International Potato Center

CIP is supported by the Consultative Group on International Agricultural Research

July 02, 2015

The MSC coordinator
University of Nairobi
School of Computing and Informatics
Nairobi
Kenya

Dear Sir,

PERMISSION TO USE ORGANIZATION DATA SETS

The International Potato Centre (CIP) is an International organization that works in developing countries to improve the productivity of potato and sweet potato and thereby improve the lives of poor farming families around the world. CIP operates its Regional Office for the Sub-Saharan Africa from the International Livestock Research Institute (ILRI) campus at Uthiru, Upper Kabete, Nairobi.

We wish to confirm that Mr. Luka Mwangi Wanjohi is an employee of the International Potato Center. Mr. Wanjohi works as a Data Manager for the Sweetpotato for Profit and Health Initiative (SPHI) Project. Mr. Wanjohi has set up a monitoring and evaluation system that uses Android smartphones and we are glad to allow him to use this work as the basis for his MSC project at your school. The system is being set up in Nigeria at the moment.

The project is covering all the expenses related with setting up and piloting the system. We look forward to positive outcomes from the research work being conducted by Mr. Wanjohi.

Yours faithfully

Jan Low
Principal Scientist & Sweetpotato for Profit and Health Initiative (SPHI) Leader

CC Dr. Elisha Obade (MSC panel chair)
Mr. Christopher Moturi (Supervisor)

ILRI Campus, Old Naivasha Road, P. O. Box 25171, 00603, Nairobi, Kenya
Tel: 254 20 4223000; Fax: 254 20 4223600/4223001; From U.S.A.: Tel: 1-650-833-6660; Fax: 1-650-833-6661
Email: cip-nbo@cgiar.org; Website: www.cipotato.org

APPENDIX B: STATA DATA IMPORT CODE

```
*DO FILE TO IMPORT INDIVIDUAL MULTIPLIER REGISTRATION DATA INTO STATA
*CREATED 13-AUGUST-2015
*LUKA WANJOHI
*INTERNATIONAL  POTATO CENTER - NAIROBI
*VERSION 1.0

*import excel data into STATA
*File extension can either be .xls or .xlsx

clear
import excel using "D:\DATA_MAIN\04 ME\03 ODK\10 STATA IMPORT\02 DVM REGISTRATION\sample\GH 02 INDIVIDUAL MULTIPLIER REGISTRATION V1.3.xlsx", sheet("main_sheet") firstrow


*Label variables created

label variable COUNTRY  "Country for multiplier"
label variable ADMIN1CD "1st level location of home"
label variable ADMIN4CD "2nd level location of home"
label variable ADMIN5CD "3rd level location of home"
label variable MULTCD   "Multiplier code"

rename MULTIPLIER_NAMESFIRST_NAME MULT_FIRST_NAME
rename MULTIPLIER_NAMESLAST_NAME MULT_LAST_NAME

label variable MULT_FIRST_NAME  "First and middle name of multiplier"
label variable MULT_LAST_NAME   "Last name of multiplier"
label variable CELLPHONE        "Cellphone number of multiplier" //cellphone number import not working

rename FIELD_GPS_READINGLatitude GPS_LAT
rename FIELD_GPS_READINGLongitude GPS_LON
rename FIELD_GPS_READINGAltitude GPS_ALT
rename FIELD_GPS_READINGAccuracy GPS_ACC

label variable GPS_LAT      "Field GPS latitude"
label variable GPS_LON      "Field GPS longitude"
label variable GPS_ALT      "Field GPS altitude"
label variable GPS_ALT      "Field GPS accuracy"
label variable SEX          "Sex of multiplier"
label variable AGE          "AGE of multiplier in years"
label variable YEARBEG      "Year started multiplying sweetpotato"
label variable MONBEG       "Month started multiplying sweetpotato"
label variable GROWBEF      "Years of experience growing sweetpotato"
label variable SIZEFARM     "Number of hectares on farm"
label variable SIZEVALLEY   "Number of hectares in lowlands/valley bottoms"
label variable CATEGORY     "Category of farmer"
label variable CROPSELL1    "Most profitable crop"
label variable CROPSELL2    "2nd most profitable crop"
label variable CROPSELL3    "3rd most profitable crop"
label variable SELLSSEED    "DVM produces other types of seed/planting material besides SP"
label variable SELLSROOTS   "DVM produces/sells sweetpotato roots"
// how to deal with text fields - WATER_ACCESS
label variable IRRIGATION_EQ    "DVM owns irrigation equipment"
// how to deal with text fields - DESC_EQUIP
label variable HA_IRRIGATED "Number of hectares under irrigation"
// how to deal with text fields - SOIL_TYPE

rename SOILGROUPSOIL_QUAL SOIL_QUAL
rename SOILGROUPFERTILIZER FERTILIZER
rename SOILGROUPMANURE MANURE

label variable SOIL_QUAL    "Assessment of quality of soil for sweetpotato production"
label variable FERTILIZER   "DVM uses fertilizer on any crop"
label variable MANURE       "DVM has access to manure for use on crops"
label variable MEMGP        "DVM active member of a farmer's organization"
label variable NAMEGP       "Name of farmers organization that is most active in"
label variable MEMREL       "DVM active member of a religiois organization"
label variable LEADER       "DVM considered leader in community"
label variable SPOUSE       "DVM spouse assist's in sweetpotato multiplication/production"

rename DISTANCE_TRAINING_DETAILSDISTAN DISTANCE
```

APPENDIX C: PAPER MONITORING TOOL

VINE DISSEMINATION FORM (WITHOUT VOUCHERS): SWEETPOTATO FOR HEALTH AND WEALTH IN NIGERIA **COUNTRY:** 3 8 **SHEET NO.**

DAY MON: **YR:** LOCAL GOVER (AD4): VILLAGE (AD5)

NAME OF VINE MULTIPLIER: NAME OF MONITOR/EXTENSIONIST:

VARIETY #1: MOTHERS' DELIGHT 0 5 5 AMOUNT DISTRIBUTED PER PERSON UNIT 1- CUTTINGS 2- KGS LABELED? 0-NO 1-YES

VARIETY #2: KING J 0 5 4 AMOUNT DISTRIBUTED PER PERSON UNIT 1- CUTTINGS 2- KGS LABELED? 0-NO 1-YES

No.	**FIRST** & MIDDLE NAME	**LAST OR FAMILY** NAME	SEX 1-M 2-F	AGE (YRS) 1-<25 2-25-50 3->50	NAME OF VILLAGE WHERE LIVES IF DIFFERENT FROM ABOVE	Code	HH has U5? 0-No 1-Yes	HH has U2? 0-No 1-Yes	Grew SP before? 0-No 1-Yes	Will grow in 1-Up 2-Low	CELLPHONE NUMBER (OWN OR CLOSEST CONTACT)	TOTAL MONEY RECEIVED (0 if given out free) (Naira)	SIGNED THAT RECEIVED

Variety Codes: 1- MOTHER'S DELIGHT 2- KING J