THE WARC GROUP

INSIGHTS INTO SMALLHOLDER FARMERS' WILLINGNESS TO USE MOBILE TECHNOLOGY IN SIERRA LEONE

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I. Acknowledgements

In assembling this report, we were privileged to work with a wonderful team of entrepreneurs, experts in the field and academia. Our heartfelt thanks to Emiliano Mroue, Anthony Orlando, Mireia Romañach and Christopher Zaw for their invaluable insights and guidance to develop this research report, and to Brima Sesay and Mariam, for their time and effort in interpreting our interviews, we would not have been able to complete objective without your help.

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Finally, we would like to thank the Tormabum community for welcoming us with open arms and sharing their hopes and aspirations with us. Their experience and knowledge was an incomparable source of inspiration that motivated us to push through the challenges of the process.

II. Executive Summary

This workshop was conducted as the result of a partnership between a group of Columbia SIPA graduate students and the West African Rice Company Group (WARC). Its main objective was to analyze the level of access and understanding of mobile technology among smallholder farmers in Sierra Leone and how it can be used to improve their living conditions. WARC is planning to develop a smartphone application to assist smallholder farmers to increase their yields, thereby generate additional income and, subsequently, escape the poverty trap. WARC's vision is to pilot the project in Tormabum, in Bonthe District of Sierra Leone, where WARC is presently working, and then expand regionally, nationally, and eventually globally. The app will include weather information, farming technique tutorials, and micro-financing opportunities, among other functions. Additionally, it will send push notifications for emergency situations and key seasonal data in the farming process. As such, the proposed app will allow farmers to increase the productivity of their plots, augment the desirability of their crops (and thus their market value), and, ideally, improve their living conditions.

Therefore, we began with an analysis of WARC's business model and objectives, as well as a thorough research on the agricultural, historical, political, and technological infrastructure of Sierra Leone. Specifically, we analyzed the possible challenges, risks, and considerations needed for the success of the project, including cell service coverage, electricity accessibility, and illiteracy. Following this contextual analysis, we explored best practices, success stories, and existing apps available in low-income countries, to gain insight and guidance for the project. We also conducted a detailed research of user experience and user design theories in order to better understand ways to successfully develop an app that takes into consideration the contextual and demographic characteristics of rural Sierra Leone (i.e. education levels, literacy, sex, age, etc.). We used this research to create a collection of paper-based, prototype-based, and app usability tests to analyze what farmers preferred in terms of app features and how they interacted with the idea of a smartphone app. The survey analysis involved testing, survey questions, and general interactive conversations with WARC farmers. This report will present the results, conclusions, and recommendations derived from this survey process.

III. Project Introduction

Project Objectives

The West African Rice Company Group (WARC) is interested in furthering their understanding about how people in rural Sierra Leone currently engage with technology, especially in areas with a high proportion of less-educated and illiterate farmers. They are planning to launch several technology-driven programs to support smallholder farmers and their families, with the objective to help them out of the poverty trap.

Last year (2016-17), a team of SIPA students worked with WARC to develop an in-house e-farming digital platform, *Zinnia*, intended to connect farmers with appropriate and affordable inputs, market information, and agricultural knowledge. Our team's primary objective is to supplement the previous team's work by exploring the potential of rural farmers in Bonthe District to effectively adopt and recurrently use technology-enabled platforms to increase yields and farm productivity.

To achieve this objective, it was imperative that we understood the existing rural technological infrastructure in Sierra Leone. Access to and use of smartphones is currently a clear obstacle, particularly among the least educated. However, as such technology becomes cheaper and more accessible, WARC and other local tech experts expect that the most remote areas will have full coverage in the next few years.

Therefore, we analyzed the current landscape of technology diffusion in rural Sierra Leone and farmers' access to and familiarity with smartphones. In addition, the project focused on understanding the farmers' willingness to access WARC platforms through these devices and their ability to comprehend and internalize the information provided. Thus, we worked with WARC farmers to gauge their interest in the project as well as the feasibility and profitability of introducing a technological platform like a smartphone app for information sharing and learning.

The research more specifically focused on the following factors:

- *Wealth*—How do the rural poor and extreme poor currently engage with technology, and how does this differ from the non-poor?

- *Education*—What are the best ways to engage people with low literacy and numeracy skills through technology? How can relatively complex ideas and concepts be conveyed to them, and how can they communicate back?

- *Language*—How does language play a factor or role in technology adoption for those members of the population where English is not the primary language?

- *Age*—Are there significant differences in technology usage between children, youth, adults, and the elderly? Does age play a factor in willingness to take up a technology?

- *Technology Adoption*—What strategies can WARC use to better engage different segments of the population in Bonthe District through mobile technology? Is gamification a way to engage some users and encourage them to continue to use the technology? Are there other methods to explore when targeting specific subgroups in the rural communities where WARC operates?

Apart from answering the above research questions, we also considered how to encourage farmers to continue engaging with mobile technology and effectively utilize the information learnt.

Deliverables

ID	Deliverable	Explanation	Due Date
1	**Detailed work-plan**	A comprehensive document that provides details of the organization, project objectives, methodologies and other strategies devised to implement the project.	December 2017
2	**Presentation of preliminary findings to WARC Group**	Executive presentation of project, methodology, main findings and recommendations to WARC staff.	March 2018
3	**Draft outline of final report**	An outline of the final report to be compiled.	March 2018
4	**Draft final report**	A compilation of procedures adopted for the project along with findings and results.	April 2018
5	**Final presentation to faculty and students**	Executive presentation of project, methodology, main findings and recommendations to SIPA faculty and community.	April 2018
6	**Final report**	A final report of the project including all the details of strategies and implementation along with final results and recommendations.	May 2018

Team Organization

Position Title	Team Member	Responsibilities
Project Manager	Helena Toledo Quiroz	Coordinates team communications, plans and facilitates team meetings, organizes work flow, and enforces deadlines.
Faculty Contact	Niki Shrestha	Acts as the liaison between We and Faculty Advisor Tom Casazzone, serves as initial point of contact, coordinates meeting times, initiates conversations, and provides updates.
Client Contact	Carlos Alberto Rubio Pimienta	Acts as the liaison between We and the client, serves as initial point of contact, coordinates meeting times, initiates conversations, and provides updates.
Budget Officer	William Gangware	Attends EPD budget meetings, develops budget (with assistance of We), manages reimbursement process for team members.
Prototype Manager	Alok S. Viswanath	Organizes, allocates, and manages the creation of testing prototypes for the field.
Research Paper Coordinator	Jhalak Trivedi	Coordinates and organizes the topical research and testing results to be presented in the final paper.

Research Questions for Success

The usage of *Zinnia* and other technology-enabled platforms in Sierra Leone, as presented by WARC, raised several relevant research questions.

The primary research question is the following:

> ***How effective would a technology-enabled platform, like Zinnia, be in connecting smallholder farmers in Sierra Leone with information about appropriate and affordable inputs, market information and agricultural best practices, and how can it become more effective?***

After conducting interviews and analyzing results, we could conclude that the project effectiveness depends on five main variables:

1. **Preliminary research**—it is crucial to the determine which sectors of society will be most suitable and willing to use the smartphone platform in its initial stages, and how they will access the technology.

- Are there other organizations doing similar work in the region (Western Africa)? What can we learn from their work?
- What types of technology or platforms could be used for rural farmers to learn about affordable inputs, market information, and agricultural best practices? What are the advantages and disadvantages of each type?

2. **Access to technology/cellular data coverage** –although the platform will be designed to use a minimum amount of data coverage, and will have a simple and accessible software, the community's accessibility to both affects its usability.

    - Who owns smartphones in rural Sierra Leone (men, women, people of certain levels of education or income, etc.)? Do households have multiple? Do neighbors share?
    - What is the cellular data coverage in Sierra Leone? Is the coverage or access increasing or decreasing?
    - How feasible is the cost of mobile technology? What is the electricity coverage and means to charge smartphones?

3. **Digital literacy of smallholder farmers of different demographic groups**—smallholder farmers in Sierra Leone have different levels of education and diverse experiences with technology. Some of them may even need initial training to familiarize themselves with digital platforms.

    - How do the rural poor engage with technology?
    - What are the best ways to engage people with low literacy and numeracy skills through technology? What is the best way to communicate with people of lower education levels that is not frustrating or too difficult to understand?
    - Are there differences in technology usage between children and youth, adults, and the elderly?
    - What is the primary language of the farmer? What is the best language to use for understanding? What can be done to resolve a language barrier?

4. **Desire/readiness of smallholder farmers to actually use the platform**—even if the platform is developed and uses a simple and accessible framework, its success will ultimately depend on the farmers' willingness to use it and learn from it.

    - Do people like the platform and will they continue to use it?

5. **Sustainability of usage**—the platform must be periodically updated to take into account the smallholder farmers' learning process, and their ability to incorporate the information provided into their farming practices. It should also be updated to take into account changes in the technology infrastructure of the country and the smallholder farmers' access to smartphones and other digital platforms.

    - What is the best way to newly engage the rural poor through technology platforms by demographic group/district?

IV. Contextual Background

Country Background

Figure 1: Country Map
("Sponsorship of a VSO Volunteer Nurse to Bonthe, Sierra Leone," n.d.)

07/05/18 13:46The Republic of Sierra Leone is a country in West Africa, bordered by Guinea to the Northeast, Liberia to the Southeast, and the Atlantic Ocean to the Southwest ("Sierra Leone country profile," 2018). It has a population of 7,075,641 (based on the 2015 national census) and its official languages are English, Krio (Creole language derived from English) and a range of African languages ("Sierra Leone country profile," 2018). Sierra Leone is officially a secular state, but 78% of the population practices Islam, 20.9% is Christian and 1% adheres to a traditional African religion("Sierra Leone country profile," 2018). It is home to sixteen ethnic groups, the largest and most influential of which are the Tenme (35% of the population and predominant in the North and areas around the capital) and the Mende (31% of the population and predominant in Southeast Sierra Leone) ("Sierra Leone country profile," 2018). Freetown, located in the Western area, is Sierra Leone's capital; with a population of 1,050,301 people, it is the country's largest city and its economic center. ("Sierra Leone country profile," 2018)

Political Structure

On 27 April 1967, Sir Milton Margai led Sierra Leone to independence from Great Britain and became the country's first Prime Minister. Under the 1995 Constitution, Sierra Leone became a republic with an executive President, a multiparty democracy, and a unicameral Parliament. Presidential and parliamentary elections are held at least every five years, under universal adult suffrage and proportional representation. ("Sierra Leone Government," n.d.)

Ernest Bai Koroma won a second and final term as President of Sierra Leone in November 2012, in the first elections the country has held without United Nations supervision since the end of the civil war in 2001; it also marked the first time in Sierra Leone's history that an opposition party peacefully assumed executive and legislative power in competitive elections ("Sierra Leone," 2012). President Koroma, an insurance broker by profession, has pursued free-market policies and encouraged foreign investment to rebuild the damage caused by the

civil war ("Sierra Leone," 2012). Since his mandate began, Sierra Leone has made considerable progress in improving governance, respect for human rights, and the rule of law, even though the country remains quite low on other major international indices. Additionally, Sierra Leone's government and citizens remain dependent upon security guarantees associated with foreign military training programs and on considerable foreign aid to provide for basic services("Sierra Leone," 2012).

Sierra Leone has a vibrant civic culture, with numerous non-governmental organizations (NGOs) that pursue popular causes and monitor government performance. NGOs commonly highlight deficiencies in the implementation of official policies, corruption, and poor public service provision. NGO coalitions influence the crafting of legislation through advocacy efforts, often in tandem with foreign donors("Sierra Leone," 2012). Additionally, Sierra Leone's constitution protects the freedom of expression and the press. More than fifty licensed newspapers report on current affairs, and many are critical of government officials and their performance. Portable battery-powered radios provide listeners with information about democratic processes and policy issues, and provide diverse guests with access to the airwaves throughout the country. ("Sierra Leone," 2012)

However, one persistent challenge is the ability of the judicial branch to be independent, impartial, and nondiscriminatory. Delays in the administration of justice, due largely to lack of resources and personnel, have led to the popular perception that corruption often determines the processing speed and outcomes of court proceedings("Sierra Leone," 2012). Continuous procedural delays leave targets of prosecution in a state of uncertainty, and observers frequently suspect that powerful individuals exploit these conditions to target business competitors and political rivals. ("Sierra Leone," 2012)

General elections were held in Sierra Leone on March 7, 2018 to elect the President, Parliament and local councils. Incumbent President Koroma did not run for reelection, as he is constitutionally ineligible ("Sierra Leone," 2012). The three major presidential candidates were current Foreign Minister Samura Kamara, candidate for the ruling All People's Congress (APC) party; former Sierra Leone military junta ruler Brigadier Julius Maada Bio, candidate for the main opposition Sierra Leone People's Party (SLPP), and former United Nations senior official Kandeh Yumkella, candidate for the newly formed National Grand Coalition—a popular progressive liberal political party that was formed by disgruntled former members of the SLPP("Sierra Leone," 2012).

No presidential candidate received the 55% of the vote required to win in the first round, meaning a second round of voting was held on March 31, 2018 between the top two candidates, Julius Maada Bio and Samura Kamara, who were separated by under 15,000 votes in the first round ("Sierra Leone," 2012). Maada Bio won the election in April 2018 and was sworn in as president.

Civil War (1991-2002)

Sierra Leone was embroiled in a civil war that resulted in the death of over 50,000 civilians. It began in March 1991, when the Revolutionary United Front (RUF), a rebel group led by Foday Sankoh, launched a campaign to topple the corrupt military government of President Joseph Momoh and seize the country's resources ("Sierra Leone," 2012). During its campaign to gain control of the country, the RUF employed brutal tactics including murder, physical

mutilation, rape, and the recruitment and abduction of child soldiers. At the war's peak, the RUF controlled large swaths of territory and diamond fields in the countryside.

On July 7, 1999, with the assistance of the international community, President Kabbah and RUF leader Sankoh, signed the Lome Peace Agreement, which made Sankoh Vice President and gave other RUF members positions in government("Sierra Leone," 2012). The accord called for an international peacekeeping force run by the United Nations. The UN Security Council established the Sierra Leone Mission (UNAMSIL) in 1999, and it deployed up to 17,500 peacekeeping soldiers before its mandate ended in 2005. As disarmament progressed, the government began to reassert its authority in formerly rebel-held areas. ("Sierra Leone," 2012)

By early 2002, some 72,000 ex-combatants had been disarmed and demobilized, although many still awaited reintegration assistance. On January 18, 2002, President Kabbah officially declared the end of the civil war. In May 2002, he was re-elected to a five-year term in a landslide victory for his party. The RUF political wing, the RUFP, failed to win a single seat in Parliament. Following the end of the UNAMSIL mandate, the UN established the UN Integrated Office in Sierra Leone (UNIOSIL), which assumed a peacebuilding mandate. (Agricultural Statistics Bulletin, 2011)

Social and Economic Background

Sierra Leone is one of the top ten diamond producing countries in the world; in fact, the export of diamonds, iron, gold, and other minerals constitutes the country's main source of income. Sierra Leone's economy proved resilient in the face of two major shocks in 2014/2015: the Ebola epidemic and the collapse of iron ore prices (African Development Bank Group, 2011). Economic growth has resumed, however, and remains upward, supported by new investments in mining, agriculture, and fisheries. The recovery underway, according to the International Monetary Fund projections, is expected to remain sustainable over the medium term. Real Gross Domestic Growth (GDP) is projected to recover from—20.6% in 2015 to 5.4% in 2017. (African Development Bank Group, 2011)

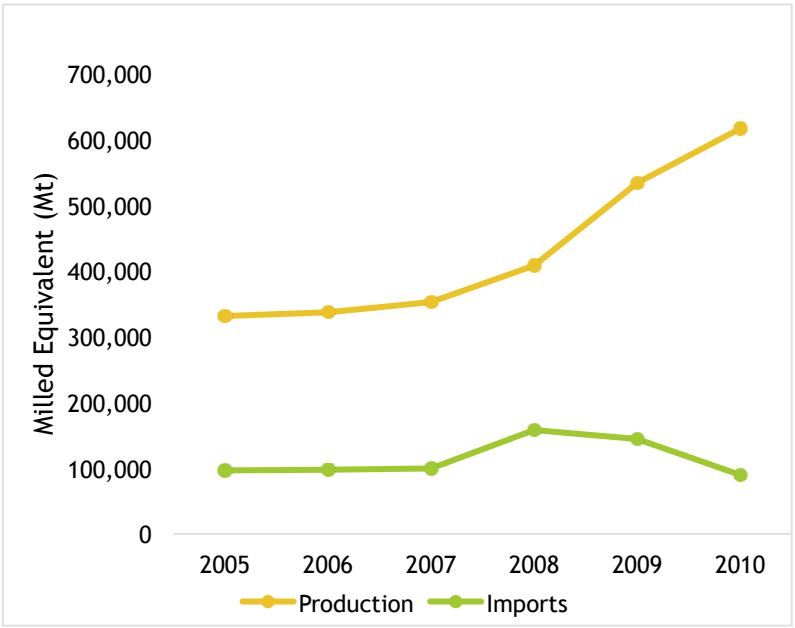
As an attractive and potentially profitable economy, Foreign Direct Investments have been growing over the past few years, currently exceeding Ghana, Guinea, Niger and Senegal. In terms of agriculture, for instance, the country has managed to attract over $200 million dollars, pledged in investment for the commercial growth of rice and sugar, production of bioethanol, and the cogeneration of electricity (African Development Bank Group, 2011).
However, Consumer Price Inflation continues to rise on account of exchange rate pass-through and accommodative monetary stance. Rising from a base of 9.5% in December 2015, inflation reached 17.41% in December 2016. Exchange rate pressures remain unabated. The local currency (the Leone) had depreciated by 28.73% in December 2016 (year-on-year). (African Development Bank Group, 2011)

While improvements have been made, most citizens still face a daily struggle for survival. The Human Development Index, lists Sierra Leone as 180 out of 187 countries, and the average life expectancy is just 48 years. The gross national income per capita is $737, but income inequality is high and 70.2% of the population live in extreme poverty ("Sierra Leone After the Civil War," 2012). Half of the working age population engages in subsistence agriculture and only 51% is literate.

Education in Sierra Leone is legally required for all children until the secondary level, but a shortage of schools and teachers has made implementation impossible. The Civil War resulted in the destruction of 1,270 primary schools by 2001 ("Sierra Leone After the Civil War," 2012). Since the end of the war, however, the situation has improved with the reconstruction of many schools and the doubling of the primary school enrollment rate from 2001 to 2005. In spite of this, the rate of completion of primary education remains low, at only 69.5% of all children. The educational attainment of girls is even lower due to cultural beliefs in some areas of the country (67.6% in 2013) ("Education in Sierra Leone," n.d.). Therefore, the main issues standing in the way of Sierra Leone's future development continue to be persistent poverty, youth unemployment, and corruption, which are ultimately hindering the development of prompt social services.

Agricultural Sector

Figure 2: National Production of Rice/ Rice Import (Mt Milled)



The agricultural sector represents 71.1% of the country's total GDP and occupies 61.1% of the population. The main agricultural products are: rice, coffee, cocoa, palm kernels, palm oil, peanuts, cashews, poultry, cattle, sheep, pigs, and fish. Despite vast natural resources and prime agricultural land, Sierra Leone fails to develop the sector, relying heavily on food imports and international aid to feed its population; rice imports are forecasted to total up to 250,000 tons in 2016, an increase of 300% since 2005 (WARC Group, 2017). (Agricultural Statistics Bulletin, 2011)

Similarly, the country imports around 90% of its total egg consumption, approximately 44 million eggs in 2011. Moreover, hunger remains a problem in Sierra Leone, as nearly 60% of rural Sierra Leoneans are estimated to be food insecure (WARC Group, 2017).

Poor yields are the main driver for the low aggregated food production output, which in turn hinders farmers' competitiveness. Only a mere 4% of farmers in Sierra Leone produce enough to meet their family's needs for rice year-round ("Sierra Leone - Comprehensive Food Security and Vulnerability Analysis, December 2015 | WFP).

Figure 3: National Rice Production and Self-Sufficiency for Period 2001-2010

Year	Area (Ha)	Yield (Mt/ha)	Production (Mt)	Milled Equivalent (Mt)	Population	National Requirement (Mt Milled)	Self-Sufficiency (%)
2001	258,850	1.20	310,620	186,372	4,725,033	491,403	37.93
2002	343,142	1.23	422,065	253,239	4,814,808	500,740	50.57
2003	356,142	1.25	445,633	267,380	4,906,290	510,254	52.40
2004	426,772	1.27	542,000	325,200	4,999,509	519,949	62.54
2005	427,907	1.29	552,000	331,200	5,094,500	529,828	62.51
2006	422,556	1.33	562,000	337,200	5,216,890	542,557	62.15
2007	432,356	1.36	588,004	352,802	5,343,200	555,693	63.49
2008	475,592	1.43	680,097	408,058	5,473,530	569,247	71.68
2009	499,111	1.78	888,417	533,050	5,607,930	583,225	91.40
2010	549,022	1.87	1,026,671	616,003	5,746,800	597,667	103.07

(SEWA Farm Inc., 2018)

The main causes for their low yields are:

1. **Unavailability of improved seeds**—Farmers rely heavily on their own seed production or the intermittent distribution of seeds by the Ministry of Agriculture, Fisheries, and Food Security (MAFFS). Seeds saved by farmers are typically stored in poor conditions, mixed varieties and in some cases contaminated by weed seeds. In addition, the continuous multiplication of a seed variety results in purity loss and a consequent reduction of yield.

2. **Poor farming techniques**—Rudimentary and outdated farming techniques are common in Sierra Leone, with farmers often failing to provide sufficient crop care, such as field weeding and pest management. Additionally, farmers are ill prepared for climate change and weather unpredictability, with floods causing complete harvest losses and depleting soils, which can be combated with good agricultural practices.

3. **Lack of access to technology**—In Sierra Leone, 99.9% of farmers are using hand tools rather than mechanized farming. Being limited to manual tools means that highly labor-intensive activities such as land preparation limit the size of a plot that an agricultural household can cultivate, as well as the quality of its preparation.

4. **Degradation of natural resources**—Mono-cropping and excessive extraction of minerals from the soil are putting farmers' lands at risk. (WARC Group, 2017)

Therefore, introducing good agricultural practices, high quality seeds and modern farming equipment will maximize farmers' yields and aggregate food production. This will enable farmers to increase competitiveness against cheap imported commodities and act as

responsible caretakers of their natural resources avoiding practices linked to degradation. (WARC Group, 2017)
The Government of Sierra Leone's Agenda for Change identifies agriculture as one of the priority sectors required to sustain economic growth, socio-economic recovery and broad-based poverty reduction. Over the past five years, the government's strategy in agriculture has been driven by the Smallholder Commercialization Program, which focuses on the intensification, diversification and commercialization of smallholder agriculture (through improving value-addition and access to marketing). The program is financed through a US$50 million Global Food and Agriculture Development Fund, granted by the International Fund for Agricultural Development and the UN Food and Agriculture Organization.

Technological Infrastructure

As of 2016, over five million people had access to electricity, however the rate of electrification in rural areas stood at only 1%. In terms of communications, 17,000 people had access to fixed telephone lines (2016 estimate), which means there was less than one subscription per hundred inhabitants. On the other hand, close to six million people owned a mobile cellphone in 2016, which means that there were 104 cellular subscriptions per 100 inhabitants ("The World Factbook — Central Intelligence Agency," n.d.)

This proves that the mobile-cellular service has grown rapidly from a small base, overcoming the deficiencies of the fixed-line sector. Finally, in terms of Internet usage, in 2016, there were 708,615 Internet users in Sierra Leone; close to 11.8% of the population ("The World Factbook — Central Intelligence Agency," n.d.)

The Information and Communications Technology sector is enjoying vibrant growth and it holds a great deal of promise for the near term. Sierra Leone liberalized its telecommunications sector over the past decade, licensing four mobile operators who compete with the national fixed line operator, Sierra Tel, under a regulatory framework administered by the National Communications Commission. Similarly, there are over ten licensed broadband internet service providers, accompanied by a flourishing expansion of internet cafes, which is how most Sierra Leoneans currently gain access. ("The World Factbook — Central Intelligence Agency," n.d.)

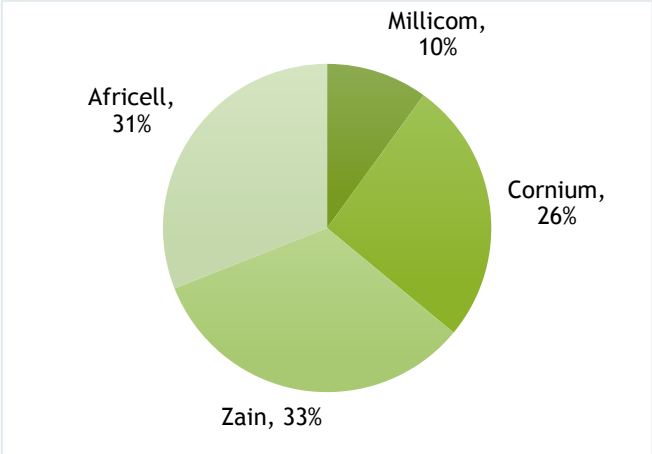
The biggest operators in Sierra Leone are:

- *Zain* – completely owned by Zain Group. Currently has over five hundred and seventy-five thousand subscribers. Represents 33% of the market.
- *Africell* – subsidiary of Lebanese owned Lintel Group. Currently has three hundred fifty thousand subscribers. Also operates in Gambia. Contributes with 31% of the market.
- *Comium* – subsidiary of Lebanese owned Comium Group. Currently has close to three hundred thousand subscribers. Also operates in Gambia, Liberia and Cote d'Ivoire. Owns 26% of the market.
- *Millicom* – completely owned by Millicom International Cellular. Currently has one hundred and ten thousand subscribers. Controls 10% of the market.
- *Orange*- purchased Airtel Sierra Leone in July 2016. Since then it has launched a modernization and expansion plan to enhance the reliability, coverage, and quality of its network. Approximately US $33 million have been invested for

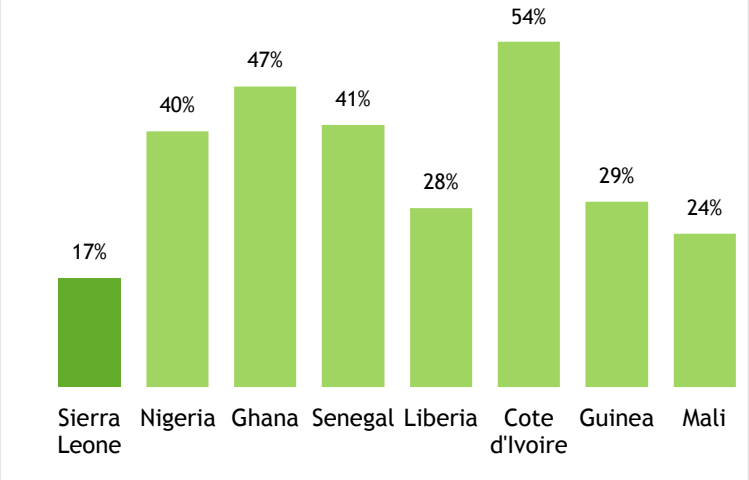
that purpose and, as of October 2017, thirty new radio sites on air had been constructed. Orange Group's strategy in Africa and the Middle East is to position itself as a leader of the digital transformation and to bring its international expertise to support the development of new digital services.

Figure 4: Sierra Leone's Technology Sector

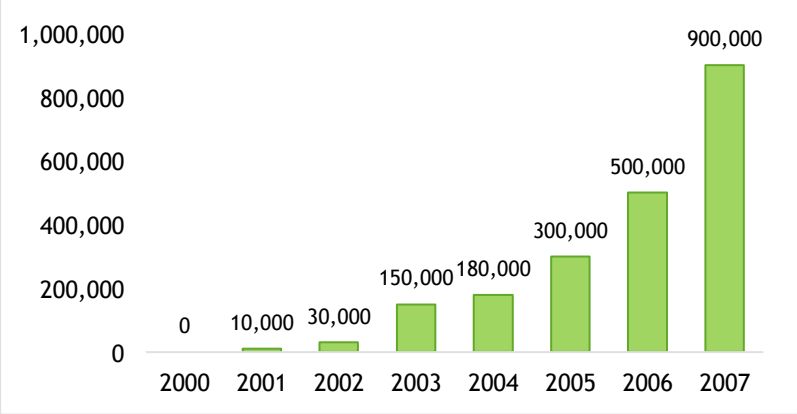
Overview



Regional Penetration Benchmarking



National Number of Mobile Subscribers



(African Development Bank Group, 2011)

Dramatic declines in the cost of internet services will only become feasible once Sierra Leone is able to pursue investment in a submarine cable and landing station linking it with Europe. However, plans are already underway for this purpose, thereby increasing consumer access.

V. Rationale for Subsistence Farming

WARC's mission to assist smallholder farmers in escaping the poverty trap, is based on sound ideas of subsistence farming and input access for smallholder farmers in low-income countries around the world. Smallholder farmers across Asia and Sub-Saharan Africa produce as much as 80% of the world's food supply, and although they comprise 90% of the five hundred and seventy million farmers worldwide, a majority of them are poor and food insecure. In the case of Africa, experts predict that the population will double by 2050, and African nations will have to double their food production to keep pace with population growth ("CTA - How Mobile Phones Are Changing the Developing World," n.d.). However, for the last twenty years, food production in the continent has not been able to keep up with population growth, given the low-productivity of most agricultural ventures. Additionally, smallholder farmers in Africa are facing constant weather changes, as a result of global warming, that have made their trade risky and unpredictable. ("CTA - How Mobile Phones Are Changing the Developing World," n.d.)

Traditionally, national governments and international organizations have focused on extension programs to deliver agricultural information to these farmers and help them increase the productivity of their fields and alleviate their precarious living-conditions. According to the World Bank, in 2016 there were more than one million agricultural extension workers in developing countries, and public agencies have spent more than ten billion dollars on public extension programs in the past five decades (Cole & Fernando, 2012). Nevertheless, the results of these efforts have been disappointing.

Limited transportation infrastructure in rural areas and high costs of delivering information in person greatly limit the reach of extension programs. Additionally, agricultural extension is provided through infrequent and irregular meetings, which limits the ability of farmers to follow-up on information delivered or to adequately respond to inclement weather or unfamiliar pest infestations. A recent representative survey in India showed that just 5.7% of farmers had received information about modern farming techniques through public extension agents. "This failure is only partly attributable to the misaligned incentives of agricultural workers; more fundamentally, it is the result of the high cost of reaching farmers in interior rural areas." (Cole & Fernando, 2012)

In the absence of expert advice, farmers seek out agricultural information through word of mouth, generic broadcast programming, or agricultural input dealers, who may be poorly informed or face incentives to recommend the wrong product or excessive dosage. Overcoming these informational inefficiencies would dramatically improve agricultural productivity and farmer welfare.

Luckily, the technological revolution has drastically altered the field and opened up new opportunities to reach the developing world's small and marginal farmers. Mobile phones in particular, could potentially offer the opportunity to deliver personalized agricultural information to farmers at low cost and in a way that is tailored to their needs and timed to coincide with key points of the agricultural cycle. ("Harnessing ICT to Increase Agricultural Production," n.d.)

An experimental study conducted in Kenya in 2017 found that sending SMS messages with agricultural advice to smallholder farmers increased yields by 11.5% relative to a control

group with no messages ("Harnessing ICT to Increase Agricultural Production," n.d.). The paper evaluated two interventions that leveraged on the growing penetration of mobile phones in the region to improve agricultural productivity, either by bettering farmer decision-making or by improving input delivery from the company. Additionally, they estimated that the increase in yields in the first round of SMS interventions generated an increase of about $43 dollars in company profits per farmer and about $54 dollars in farmer earnings, while the per-farmer cost of the program was just thirty cents. ("Harnessing ICT to Increase Agricultural Production," n.d.)

The findings of this study were in line with a similar one conducted by Cole and Fernando in 2016, who showed that in India, in response to a mobile phone-based program, *Avaaj Otalo* (AO), farmers increased the adoption of more effective and less hazardous pesticides, and in turn increased their crop yields. The application allows farmers to call a hotline, ask questions and receive guidance from agricultural scientists and local extension workers. The service also includes weekly push content, delivering time-sensitive information such as weather forecasts and pest planning strategies directly to the farmers. AO significantly changed the farmers' sources of information and those who were granted access to it were significantly more likely to adopt agricultural practices and inputs recommended by the application. Finally, the study estimated that for every dollar invested in AO, there was a return of $10 dollars, with the return for a two-year subscription at more than $200 dollars. (Cole & Fernando, 2012)

However, the adoption of mobile-based programs and applications in Africa still faces some challenges. The majority of cell phones used in the continent are what we would call basic or feature phones, capable of calling, texting and maybe basic internet browsing. According to the Pew Research Center, an average of 17% of people in Sub-Saharan Africa still do not own a cellphone, but more than half of those who do not own a phone, can access one sometimes. Additionally, there are institutional challenges in the industry. Critical infrastructure is still required to truly digitally transform agriculture in Africa. The continent does not have a comprehensive soil map similar to the US Web Soil Survey to provide soil data and information. Similarly, most of the farms are in areas with limited connectivity, making full technology integration in real time challenging. Above all, entrepreneurs will have to strive to change the farmer's mindset. Just as many farmers initially rejected inorganic fertilizers, fearing that they would irreversibly poison the land, individuals may be resistant to changing their farming methods. Agro-tech pioneers must turn farmers into believers by using field demonstrations to prove that the new technologies can deliver better results. (Ekekwe, 2017)

In spite of the challenges, digital technology has opened up a vast untapped potential for farmers, investors and entrepreneurs to drastically augment the efficiency of food production and consumption in Africa. From precision farming to an efficient food supply chain, technology could bring about major economic, social, and environmental benefits. In particular, it could raise the productivity of smallholder farmers, increase their yields, and improve their living conditions. In a word, mobile-based programs have the potential to alleviate poverty in Africa's poorest nations and thus should be greatly encouraged and supported.

VI. WARC Background

Who is the WARC Group?

Established in 2011, the WARC Group aims to play a critical role in Africa's agricultural revolution by integrating technology into indigenous farming communities and contributing to fair and rapid rural development. Their mission is to transform rural Africa by creating conscious economic growth. They believe in business approaches to development and are convinced that the interaction between people and technology can create real structural change. Their work is based on the design and distribution of smart technology business models that enable farmers to access the best available machinery, agricultural practices, and technical advice in a way that is economically beneficial for all parties. WARC Group is based on Freetown, Sierra Leone, and its team is composed of fourteen expats and over 120 local staff. ("About | WARC Group," n.d.)

WARC Group's Organizational Structure

WARC Group operates across three areas ("About | WARC Group," n.d.):

1. **WARC Production**—a social enterprise with the goal of increasing agricultural production levels through the empowerment and development of the local community. After five years of commercial production in the Bonthe District, Sierra Leone, WARC Production now manages over 3,000 ha of agricultural land.

2. **WARC Consulting**—consultancy services on business and agriculture in the developing world, with a strong focus on agricultural value chains, inclusive business and bottom of the pyramid projects. WARC consultants are placed on field assignments in Sierra Leone and abroad, both in rural and urban environments.

3. **WARC Foundation**—a non-profit organization that aims to improve the livelihoods of disadvantaged families by investing in the rural communities that the WARC Group operates in. Its work focuses on promoting child development, gender equality and providing emergency relief to enable rural communities to prosper.

WARC's Household Employee Extension Program

To achieve food security in Sierra Leone, WARC supports the efforts of smallholder farmers in the country with a three-tier approach. The first is direct training on the farm, followed by the Household Extension Program (HEEP) to accelerate the transfer of knowledge, inputs, and

technology to household farmers, and finally the traditional outgrower scheme ("About | WARC Group," n.d.)

HEEP is a three-way partnership between WARC, its trainees and the trainee's household members. Through HEEP, WARC provides: high-touch, farmer-led extension facilitation, land shaping, mechanized no-till planting, and agro-chemical services.

Farmers registered in HEEP receive the same type of technology as a top of the line commercial entity. In short, the training farm functions as a tangible aspiration for the farmer, exposing him/her to new technologies. The program aims to provide:

1. Increased production for households though larger land area under cultivation, use of improved inputs, access to no-till technology, and improved agricultural practices, delivered through high-touch weekly extension meetings.

2. Reinvestment of surplus cash, where trainings and messaging encourage farmers to reinvest in their farms or in other businesses outside of agriculture.

3. Increased demand for inputs and services to make it economically viable for other service providers to enter the market. Consequently, smallholder farmers become the center of a new ecosystem.

WARC in the Bonthe District

WARC primarily operates in Bonthe District, where the training farm and HEEP program are located. Bonthe District is comprised of several islands in Southern Sierra Leone. Its capital is the town of Mattru Jong, located on the Sherbro Island. Sierra Leone's second largest city, Bo, is located about 100km south of Tormabum. As of the 2015 census, the district had a population of 200,730 people; thus, it is the least populous district in the country. The District Council Chairman and the Municipal Mayor are the highest local government officials and they are elected directly by the residents of the district. It currently has three representatives in the Parliament of Sierra Leone, all of which were elected for five-year periods and belong to the main opposition party, the Sierra Leone People's Party.

According to the 2015 census, 20% of the population was children below the age of five, 25% were between the ages of five and fourteen, and 40% belonged to the active workforce (sixteen to sixty-four years old). The World Bank survey of 2014 indicated that almost 79% of residents were rural and that the average family size was 5.5. Furthermore, according to the Wealth Index, 36% of district households are in the poorest quintile, whereas 20% are among the medium poor. Overall, the poverty level accounts for 50% of the population and the Gini coefficient is 0.3. (*Country Profile, Relief Web*, 2018)

Tormabum, the village where WARC operates, is located in the southeastern section of the Bonthe District, approximately sixty-two miles from Bo. It currently has 51,300 hectares of suitable land for mechanical cultivation. Farmers working for WARC (hereinafter called WARC farmers) specialize in the production of rice, ground nuts, cassava, potatoes, maize, vegetables, and yams, as crop production is the primary source of income for WARC farmers.

Figure 5: WARC Crop Production

Crops Produced by WARC Farmers		
Crops	**Number of farmers**	**Percentage**
Rice	112	97%
Cassava	104	90%
Potatoes	82	71%
Vegetables	78	67%
Ground Nuts	61	53%
Maize	14	12%
Yam	11	9%

Figure 6: Sources of Income of WARC Farmers

Sources of Income for WARC Farmers		
Source	**Number of farmers**	**Percentage**
Salary Job	116	100%
Crop Production	97	84%
Animal Production	34	29%
Petty Trading	23	20%
Casual Labor	22	19%
Fishing	16	14%
Skilled labor	9	8%
Driving / Riding	1	1%
Remittances	0	0%
VSLA / SILC	0	0%
Local Manufacturing	0	0%
Hunting	0	0%
Crop production, animal production and salary job	28	24%

Crop production and salary job	27	23%
Only salary job	15	13%

In terms of demographics, out of the 116 farmers that currently work for WARC, we know that 59% are male, 46% are between the ages of twenty and thirty, 61% are illiterate, and 84% are married.

Figure 7: Gender Distribution for WARC Farmers

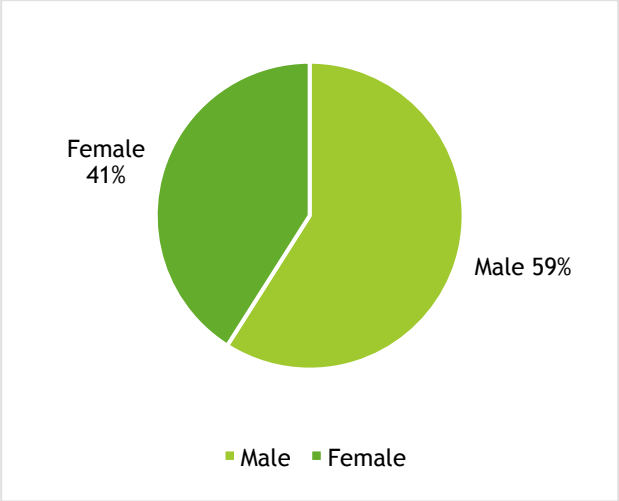


Figure 8: Age Distribution of WARC Farmers

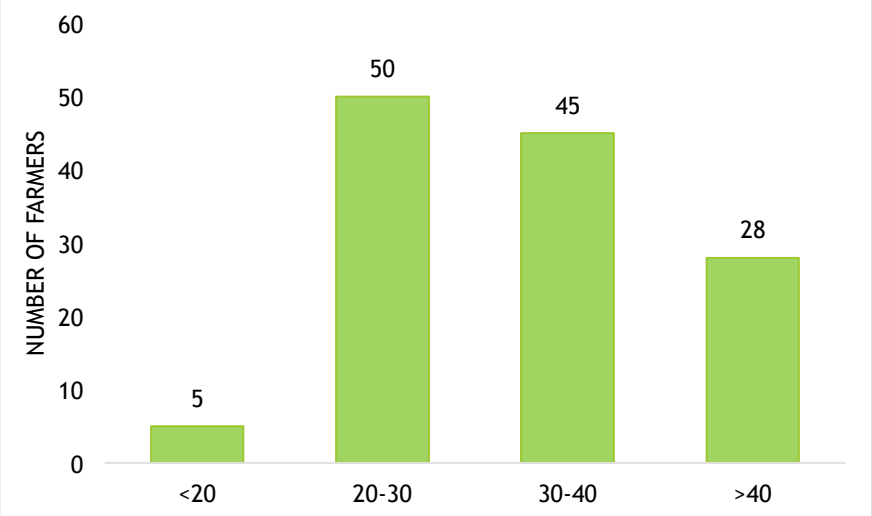


Figure 9: Civil Status Distribution of WARC Farmers

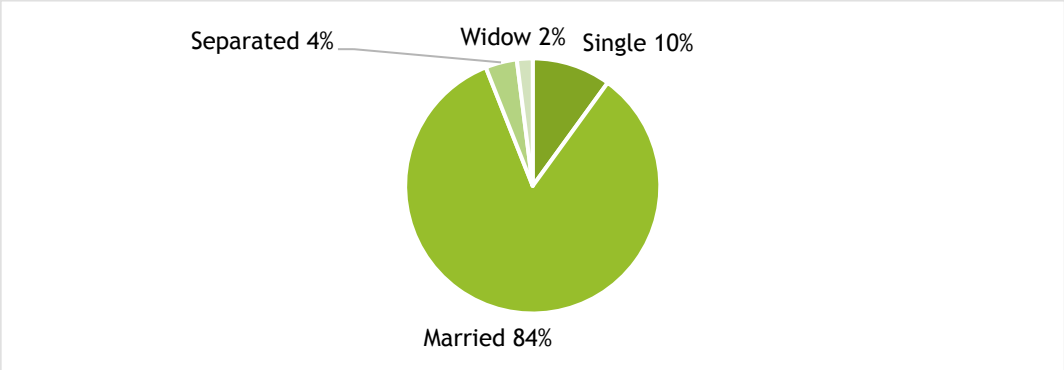
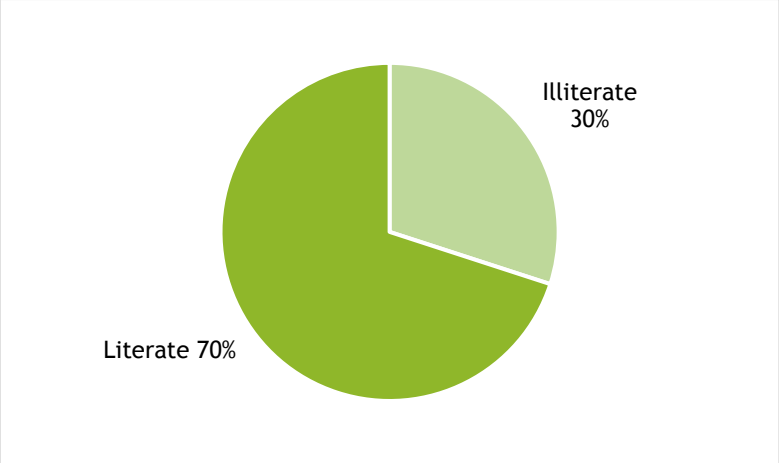


Figure 10: Literacy Level of WARC Farmers



VII. Project Methodology

In order to achieve our project's goals, we defined a five steps methodology which was embodied in a detailed project plan that guided our activities for the past 6 months:

1. **Preliminary Research and Preparation**: Background research on rural Sierra Leone, access to technology, and cellular data coverage. We planned the initial trip in January by identifying potential populations for conducting interviews, as well as outlining the primary objectives of the trip.

2. **Initial Field Research (January) and Project Restructuring:** The trip in January included meetings with the WARC staff and other key informants. We conducted preliminary interviews with WARC farmers and technology companies in Sierra Leone. As a result, we restructured our research questions and project's objective and conducted further research to prepare for the trip in March.

3. **Analysis of Preliminary Field Research:** The group analyzed the data collected in January and created a plan for the March trip. We conducted several more interviews with app development firms in New York and outside to understand how to engage farmers with technology.

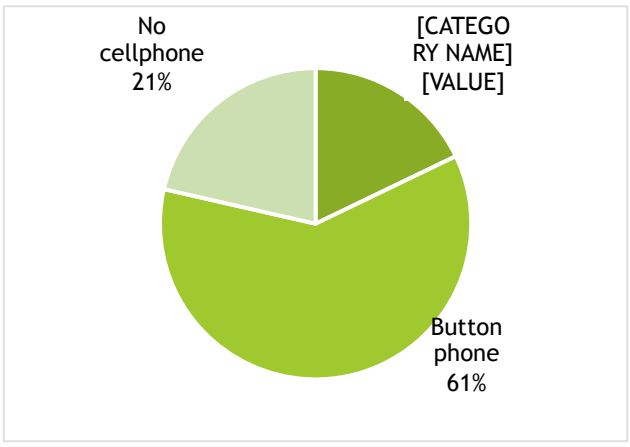
4. **Refinement of Research Framework and March Fieldwork:** The March trip focused on a methodology that involved testing app prototypes and user stories in a controlled environment to address constraints and initial recommendations discussed internally thus far.

5. **Analysis of Remaining Field Data and Preparation of Findings and Recommendations:** Upon returning from the March trip, we analyzed findings and defined the structure of our final report. We came up with final recommendations that we believe would provide WARC with a concrete set of next steps to help move the project forward.

VIII. Initial Field Research and the January Trip

Following preliminary research to better understand the contextual background of rural Sierra Leone, technology-use in low-income countries with less-educated populations, theory of subsistence farming, and the purpose of incorporating a smartphone app into smallholder farmer yield advancement programs, two of our team members (Helena and Jhalak) travelled to Freetown and Tormabum (Bonthe District) to meet with the WARC staff and the farmers. During the first days of the trip, we were able to develop a better understanding of WARC's vision and the rationale behind the project.

Figure 11: Ownership of cellphones by January interviewees



In Tormabum, part of our team, conducted informal interviews with WARC farmers and local people to explore the extent to which they use technology, especially mobile phones, and what they currently use them for. We interviewed thirteen farmers, ten community members, two members of the HEEP program, one charging station manager, and four WARC employees, sometimes with the assistance of a translator provided by WARC. Of the total people interviewed, there were fifteen males and fifteen females between the ages of 25 and 40. During the interviews, we learnt that a majority of the farmers did have mobile phones, but not smartphones.

Upon returning to Freetown, our team members debriefed the WARC staff on their findings. They also conducted interviews with local innovation labs, organizations, start-ups, and cell service providers, including Easy Solar, Sensi Hub, IDT Labs, and Africell.

A common theme in all these was the need to focus on developing a simple and easy-to-use application, in order to guarantee that farmers can actually use it. However, the main finding from these interviews was a concern with farmers' use of smartphones due to their cost and low proliferation of data service.

Most of these organizations recommended a common phone system with text messaging or voice recorded messages, since a majority of the farmers are in remote areas without

consistent cell service, lack electricity, and have limited access to cell phone maintenance stations. Considering these findings and the desires of the WARC staff, we decided to focus on a 2-3-year trajectory, with the expectation that access and coverage will greatly increase in the near future.

IX. Rationale for Testing Methodology

In order to proceed with research to test the specific features and attributes of smartphones that would be most interesting and relevant to the WARC farmers, we analyzed other existing smartphone apps and smallholder farmer technology success stories. This extensive research allowed us to understand the characteristics of the smartphone agricultural apps market in low-income remote settings and helped us incorporate ideas of user experience to develop a testing methodology that would guide WARC's long-term project. WARC hopes that after piloting an effective app with the farmers currently working for them in Tormabum, they will be able to scale it up to the national level. The research on existing apps, success stories, and user experience also supplemented our project and provided WARC with additional advice and direction.

Success Stories

The use of technology platforms and apps in agriculture has expanded across the developing world. Numerous success stories on the use of technology platforms, particularly in South East Asia, show the potential of these projects in agricultural and developing contexts. Similarly, the growing supply of agricultural apps for indigenous and rural communities proves that there is an increasing demand for mechanisms that allow organizations to increase the scope of their initiatives through technological platforms. While these organizations and companies have faced significant challenges in the implementation of these initiatives, their experiences contribute to advance our knowledge of the use of technology in developing and farming contexts.

JAT's Crop Specific Mobile Apps

In 2014, Jayalaxmi Agro Tech (JAT) launched a set of stand-alone apps (a portable application that can be run without any installation procedure) which is fully accessible once downloaded, in order to teach the low literacy farmers in India about the best agricultural practices in English and their regional languages. To overcome the limitation of poor internet connectivity and the cost of internet packages to be borne by the farmers, JAT setup a hardware device called 'Agripole' that acts as a mobile hotspot for the farmers and that stores information on best agricultural practices, health, financial and education services. It can be downloaded via Bluetooth without the need of internet connectivity (Venkat, 2016). As of August 2017, the number of downloads had reached 170,000 through partnerships with government, private and non-governmental organizations. Based on the user feedback, JAT continuously updates and adds new features to its apps. (Venkat, 2016)

The challenge that most of the farmers in rural India were illiterate was overcome by making the apps audio-visuals intensive and minimizing the use of texts ("Thehindu.com," n.d.). To make it convenient for the farmers and to ensure they would continue to download the new content from JAT, the Agripole devices were installed in places that farmers visit frequently.

When the farmers connect their device to the Agripole, their usage data is pushed and stored in the JAT's cloud servers. When the farmer has no internet connectivity, the data is sent to the cloud via SMS. JAT then uses this data to track and analyze trends in diseases and pests based on the farmer's browsing patterns ("Thehindu.com," n.d.). Each time the app is opened, the name and contact details of the user, information on crop varieties downloaded and geographic positioning, are all collected and the usage pattern is tracked.

For example, a sharp rise in the number of searches for information about a specific disease or pests in a particular region could indicate that there is an outbreak of that disease or pest. The JAT team confirms this by calling a few farmers from that affected region and later alerts other farmers through SMS so that they can take the necessary preventive measures. This platform also correlates the user data with statistics like weather patterns. ("Thehindu.com," n.d.)
Some of the identified gaps in farmers' knowledge were:

- *Improper soil selection and land preparation*: To overcome the challenge of knowing which soil is best suited for growing which crop, information on common crop varieties and the corresponding soil to use was added.

- *Improper fodder storage*: Many farmers were not storing their excess fodder in an efficient manner to enhance its preservation. Hence, their fodder application was updated to include a section on 'silage production'.

- *Poor internet connectivity*: To overcome this challenge, the apps were developed as a lightweight, standalone file so that they work offline.

- *Traditional cultivation methods are not effective to cultivate majority of the hybrid crop varieties*. Due to lack of access to industry information and lack of knowledge to cultivate other crops, the farmers continue to produce a single crop for many years even if there is no demand for it.

- *Extensions services*: The heavy reliance by farmers on extension services for advice on diseases and micronutrient deficiencies is not met because the service is available only to a small fraction of farmers. (Mohan, n.d.)

- *Inefficient timing of maintenance*: They have used reminder systems in their apps to address this issue. For example, reminding them when to plant, irrigate, apply fertilizers and pesticides, etc. (Mohan, n.d.)

Similarly, app developers highlighted the following lesson learnt:

- *App Design*: In order to create a software that was simple, the research and development process involved extensive ideation, field-testing, and focus groups.

- *Poor internet connectivity*: The challenge of poor internet connectivity in rural areas was overcome with the introduction of the 'Agripole' hardware device.

- *App circulation*: Initially, JAT tried to visit individual villages to encourage farmers to download the apps, but the costs were too high. It later chose to launch informative campaigns in places where farmers usually gathered. The outreach

campaign is now focused on AgriPole devices and the areas where they are installed.

- *Advanced technologies are not always the solution;* instead, target the basic problem you are trying to overcome.

- *Partnerships*: The use of technologies is not always linked to behavioral changes but these can be achieved effectively through partnerships.

- *Funding Limitations*: This was overcome by testing and improving on a variety of business models.

Based on this case study, we decided to include questions that would allow us to understand the type of content that farmers would be interested in learning. These questions were framed to understand the farmers' main information gaps, as well as some of the challenges they face during the farming season. Given that our purpose was to create a general methodology for any type of content, these questions are essential in understanding the motives behind a farmer's decision to use an app.

mHS City Lab

mHS City Lab developed an app for future homeowners to let them know how much their home will cost within 10% tolerance of the actual figure. It also told the user exactly how many bags of concrete, bricks, labor hours and other inputs were needed to construct a house. Users could use these estimates to edit the features in their homes and try to make them fit their budgets.

mHS City Lab used a design methodology commonly known as 'skeuomorphism'. It aims to imitate real life as much as possible, since users tend to understand real life images better than a notion of reality (Basalla, n.d.). For example, instead of showing a stick figure of a home, they would use a 3D rendering of the home. During the testing, it was found that everyone understood the real-life pictures and 3D renderings but only the younger members understood simplified pictures.

During the testing of the user interface, they included 3D looking buttons, culturally appropriate symbols and images to imply what was being done in the app. They also included a floating Question mark icon (appears on every screen) to guide users if they were confused about the next steps.

The preliminary app usability test conducted was a Marvel prototype and they chose a low fidelity design in order to focus extensively on the design ("UX Prototypes," n.d.). Then they went to the slums and observed how people interacted both with the device and the app. Users were initially frustrated as they tapped on non-functional buttons and they asked the testers to explain a lot of technical terms (septic tanks vs sewer line, for instance). After the next iteration, during the next usability test, it was found that people responded better to pictures but were confused with some culturally inappropriate ones. For example, they used images of Western toilets rather than squat toilets, which are quite common in India. Consequently, they opted for a hybrid design, which combined words and pictures in a more realistic setting. The technical and literacy limitations along with the lack of knowledge among people about construction were overcome by using this design.

The 3D imagery was designed in SketchUp and rendered using Visualizer ("UX Prototypes," n.d.). The prototypes tested were developed in Principle and Marvel and all of the user interface screens were done in Sketch. To ensure the size of the app on the phones remained small, it was rendered onto the cloud and pushed to the device when needed.

Some of the information gaps found were:

- *Language barriers:* Even though many people had phones and nearly all teenagers had smartphones, it was found that language and literacy were a barrier for many of the users, especially in colonies and slums.

- *Cultural differences*: the vast cultural differences between a U.S. product designer and the Indian users presented some interesting differences in picture interpretations. The designs were iterated and tested on a weekly basis with the users to find out which design they understood better.

Similarly, some of the lessons learnt are:

- *Cloud Technology:* Use cloud technology to increase app functionality without increasing its size.

- *Cultural Context:* Use culturally appropriate images and symbols to facilitate use among farmers.

- *Mimic Reality:* It's best to mimic real life as much as possible since users understand it better than abstractions of reality.

The experience of mHS City Lab helped guide our research and find culturally appropriate symbols and images to test with the farmers. We also decided to use the same kind of devices they currently use in order to increase ease of use. For our prototypes, we focused on simple designs that were image-based, easy to use and with very little text content. In order to test what was the best way to communicate information to farmers, we created a tutorial in video, text and audio in order to assess farmers grasp of this new content.

Current Agricultural Apps

Our research to decide what kind of content and features to test continued with a deep-dive into the current agricultural apps used in emerging markets. All over the world, farmers, NGOs, social entrepreneurs and scientists are looking for ways to transmit agricultural expertise to farmers in remote communities and help to improve their quality of life.

A selection of prominent agricultural apps in Africa:

- *iCow* - sends farmers reminders to collect and store cow's milk during their cycle. (Omolayo, 2015)
- *Vet Africa* - East African app used to diagnose farm animal diseases.
- *M-Farm* - connects farmers to goods suppliers and gives update spot prices.
- *Esoko* - connects farmers, NGOs, projects and governments to a variety of services.

- *EZ Farms* - delivers current and predicted soil moisture levels.
- *Agro-Hub* - Cameroonian app sourcing and disseminating agriculture information.
- *Cocoa Link* - Ghanaian app delivering information from agriculture experts.
- *Kilimo Salama* - Kenyan app providing climate data via text message.
- *Kuza Doctor* - Kenyan app that provides crop growth info via SMS.
- *Modisar* - farm records and livestock advice in Botswana.
- *RiceAdvice* – Android app to improve the value chain in rice production in Africa, provides field-specific management guidelines. ("Home - www.riceadvice.info," n.d.)
- *Farmerline* – access to market prices, weather forecasts, and other real-time information for West Africa farmers. ("Farmerline," n.d.)
- *AfroCenta*– based in Ghana, provides access to suppliers, market prices, and buyers, along with logistical services to ship their produce. ("AgroCenta," n.d.)
- *2KUZE* – based in East Africa, connects farmers, agents, and buyers on a digital platform toward greater pricing transparency and more effective distribution. ("Mastercard launches 2KUZE agtech platform in East Africa," 2017)

Ideologies for App Development

User Experience

While case studies and current agricultural apps help to shape the contest of the test, user experience research allows us to frame user reactions and expectations when using technology and apps. By having a user-centered design and satisfying the end needs of users, we aim to promote an engaging and usable experiences that is relevant for the users.

UX Design

User experience design (UX Design) is the process of creating products that provide meaningful and personally relevant experiences ("What is User Experience (UX) Design?," n.d.). Some of the basic principles to boost UX Design include ("10 Basic Interaction Design Principles to Boost the UX Design," n.d.):

1. **Meet the user's needs**: first and most important principle of UX design. There are many tools to achieve this goal such as observing user behavior, data analysis and building user scenarios.
2. **Follow the user's mental model**: users operate the interface based on their instinct.
3. **Consistency**: use consistent performance, operation and feeling in a product / familiar functions and scenes in order to reduce user's learning costs.
4. **Simple design**: features and design that reduce the users' cognitive and operational costs.
5. **Use simple language instead of technical terms**: users are busy people, language and text must be easy to understand and very close to general users' thoughts.
6. **Design for functional use rather than aesthetic**: functionality of product design is more important than the aesthetics, products should obey standard normal operations principles.
7. **Simplify mental process**: use the simplest way to help users achieve their goals in the shortest time.

8. **Intuitive**: correct operating parts must stand out obviously to convey the correct information to users. Users can operate the interface based on their life experiences and instinct.
9. **Allow users to make mistakes**: mistakes should be allowed to understand if it's a user or a design problem. Apps should provide effective information to guide the user back to the right operation path.
10. **Provide feedback**: when the user performs certain operations in the human-computer interaction interface, the system must give feedback to the user in the form of discoloration, shape change, vibration, light emission, and others, immediately.

Reiss Motivation Profile

Another tool of UX Design is the Reiss Motivation Profile, a standardized assessment of what motivates any person over the age of 12. The guide is useful to frame user responses to the app and identify possible methods to incentivize app use. Likewise, the motivation profile should guide developers and WARC personnel into identifying the gaps they are trying to fill by developing the app.

Figure 12: Reiss Motivation Profile Table

Reiss Desire	As a User, I Want <Something>, So That
Power	I can feel powerful and meet my goals.
Curiosity	I can gain understanding of the world around me.
Independence	I can make choices that are meaningful to me and explore possibilities about myself.
Status	I feel like I am an important person.
Social contact	I can connect with others.
Vengeance	I can compete against others.
Honor	I can feel reliable.
Idealism	I can help others and improve their situation.
Romance	I can court sexual partners.
Order	I can create an environment that feels stable and ordered.
Acceptance	I feel others feel highly of me, giving me confidence.
Tranquility	I am not scared.
Saving	I have things I own and that are mine.

Based on these patterns, apps and their features can be organized into four motivational design patterns (*Irresistible Apps - Motivational Design Patterns for Apps, Games, and Web-based Communities | Chris Lewis | Apress*, n.d.):

- *Gameful:* Patterns that exhibit a "gameful" nature, appealing to our desire to play
- *Social:* Patterns that help us connect with others
- *Interface:* Patterns related to how we interact with the interface
- *Information:* Patterns that help us manage information that we require

Another category is that of motivational dark patterns, designed to reduce users' ability to fulfill their Reiss desires:

- *Temporal dark patterns*: Patterns that cause users to incorrectly estimate how much time they will spend with an application.
- Monetary dark patterns: Patterns designed to encourage users to part with money in a way they did not expect, either by being confused into spending more money than expected, or feeling regret at the amount of money spent
- *Social capital dark patterns*: Patterns that will result in users harming their social relationships

Understanding the user experience and frameworks for app and website design allowed us to ensure that testing and recommendations for WARC were based on existing technological theory and in a language understood by the coders who will eventually be designing the app.

X. Description of Testing Methodology

Methodology Description

WARC's objective is to develop an innovative technology-based testing methodology to guide the creation of a future smartphone app to improve the living conditions of smallholder farmers. The smartphone application will provide farmers with access to weather information, better farming techniques tutorials, and micro financing opportunities. Additionally, it will send them alerts and recommendations in case of emergency situations (such as potential floods) that might affect their crops, as well as provide them with reminders during key moments of the farming process (such as the beginning of the harvesting season). Overall, WARC's goal is to create an app that provides a holistic platform for farmers' every need, allowing farmers to maximize their harvest.

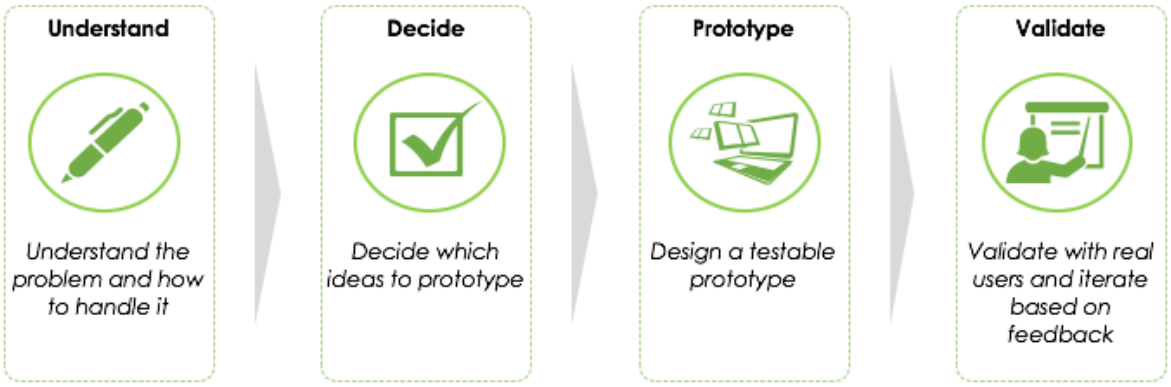
Therefore, we decided to create a collection of paper-based, prototype-based, and existing – apps tests to evaluate what farmers preferred in terms of app features and how they interacted with the idea of a smartphone app. The survey analysis involved testing, survey questions, and general anecdotal conversations with WARC farmers.

App Development Process

To develop a clear understanding of how app development and testing processes work, we conducted a series of interviews with several app development firms in New York City and abroad. The key recommendation was to follow the "design sprint," which is a framework for

answering critical questions through design, prototyping, and testing ideas with users. The sprint is comprised of four central processes: understanding, deciding, prototyping, and validating.

Figure 13: Testing Methodology



1. **Understand**—Before developing an app, the first step is to accurately analyze the problem and possible approaches. In this particular case, during constructive meetings, we discussed the many challenges that smallholder farmers in Sierra Leone face on a daily basis, the tools they can currently access, and their capacity/opportunity to utilize them. We also considered the types of technology available, existing level of mobile coverage and connectivity, in order to provide a solution that addresses the limitations and takes advantage of all areas of opportunity.

2. **Decide**—During this phase, we identified the problems that need to be addressed and hence, decided on ideas that need to be prototyped. Different possible courses of action were discussed and sketched, and a vote was eventually taken to prioritize the most feasible, desirable and durable solutions. The initial app will thus only address the most urgent matters through the most reasonable solutions. In the case of WARC's app, we chose to focus on the farmers' limited access to new and better farming techniques and decided to compare different interfaces and features that will grant them the easiest and most reliable access to such information.

3. **Prototype**—Prototypes are small samples of an app that are used to present central ideas, by building just the bare elements required to make the prototype real enough to get an authentic response from the potential users in the final phase. There is no need to build a fully functional back-end or to solve every flow in the final product. Prototypes are experiments in order to test out hypotheses. The prototypes that were designed for WARC's app will be discussed with further detail in the following sub-section.

4. **Validate**—During the validation phase, the development team will finally get to see real users interact with the prototypes and hear direct feedback from the targeted audience. Watching the users try out the prototypes is the best way to discover major issues with the design, which allows for iterations. For WARC's app, we chose to use a usability study, which involves observing the user attempting to complete a task or a set of tasks while using the product. The goal was to identify any usability issues and determine the participants' satisfaction with the product. Additionally, a stakeholder review was conducted, through which the WARC personnel provided feedback on the prototypes developed, tested them out, and identified any potential challenges. The validation process is described in further detail in subsection III.

Using the design sprint process has several benefits, making it the preferred app development process for most coders and designers. To begin with, it allows you to identify all pain points and convert them into valuable solutions. Along with effective communication, it empowers contributors to share ideas, risks, and doubts that can affect the final results. The sprint itself is meant to be short and agile, and thus it speeds up new product discovery. Additionally, it allows you to minimize risk by reducing time and budget on validating ideas. Finally, this approach builds products from a user's perspective and with their needs in mind. Overall, the design sprint is a beneficiary-centered development process that rapidly identifies problems, tests possible solutions, and provides innovative results. For this reason, we chose the design sprint methodology for testing and recommend that WARC continues to use it for future testing.

WARC's Prototypes

In terms of prototypes, we decided to work with two types of tests: paper-based and phone-based, as the combination covers a broader range of validation exercises and will allow us to partially deal with the farmers' limited access to and knowledge of technology. For this initial phase of the sprint, we chose to focus on testing both the content of the app and the features that should be included in the final design.

1. Paper-based Tests

With the paper-based tests, we will analyze which content would be most useful for the farmers and which could help them increase their yields the most. We will ask them to rank in order of preferences farming tips, micro-financing opportunities, market information, weather updates, production records, and push notifications. This will allow us to understand what their key pain points are and how the app should address them. On the other hand, we want to analyze which design display is easiest to comprehend and which they find most friendly and accessible. To do so, we will conduct a series of AB tests asking them to choose between the following pairs of options: a) help button symbol and location, b) symbols vs pictures, c) infographics vs text, and d) types of images.

2. Phone-based Tests

With the phone-based tests, we will focus exclusively on different design displays and different interfaces. Unlike the paper-based trials, this will allow us to additionally analyze the farmers' interaction with the smartphone and observe how easy it is for them to understand how the app works and what it is intended to do. Similar to the paper-based, we

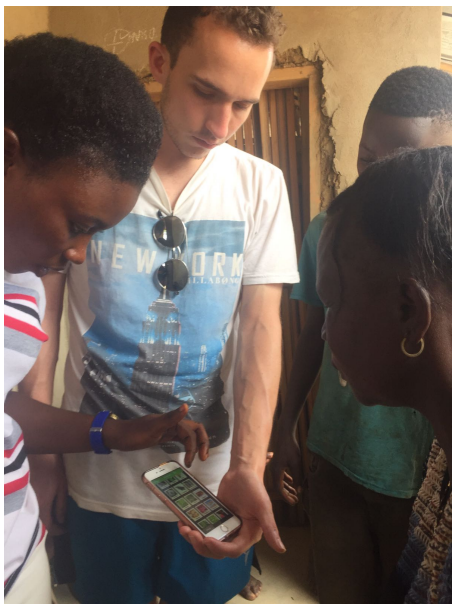
will be conducting A/B tests in which we will ask them to choose between the following pair of options: a) audio vs text vs video tutorials, b) scrolling down vs clicking, and c) swiping vs clicking,

These features were incorporated within a web-based prototype that we created for testing in the field. It included two versions where these features were intended to consecutively be presented to the respondents. In order to provide the audio/video clips, we used three different statements which included trivial information - one in text format, the other in audio and the other in video. All of these statements were written and spoken in Mende (the local language) respectively. The farmers were asked to read, listen to and watch each of these three features and answer three questions based on each of the statements. The goal of this exercise was to discern which medium was most effective to convey information to the farmers based on their answers and recalling capabilities.

Additionally, we provided farmers with an already existing farming app to observe their interaction with it, mainly what drew their attention and how easy it was for them to navigate through its different layers. We started by briefly explaining what the app was meant for and what to look for, and then asked them to "play" with it freely. This way, we were able to get insights on the types of information they are interested in receiving and the ease with which they interact with a farming smartphone app.

XI. March Trip

Trip Overview



To test the prototypes described in the previous section, four team members (Niki, Carlos, William, Alok) traveled to Tormabum, Sierra Leone, for approximately two weeks in March. The core objective of the trip was to test the prototype apps and paper prototypes with WARC's farmers and understand the landscape of mobile technology in the country. After a preliminary meeting with WARC's staff and presenting our prototypes to them, the survey questionnaire had to be modified to collect more qualitative data rather than quantitative data as per the client's requirements.

To test the features and interface best suited for smartphones, 32 interviews were conducted in Tormabum and the surrounding villages of Waah and Largo with the farmers using the prototypes. On the final day of our trip, a debriefing session was done with WARC's staff to discuss the key qualitative observations from our interviews and to get their feedback in order to prepare our recommendations.

Validation Process in Sierra Leone

After traveling to Tormabum, Sierra Leone, to conduct interviews and test prototypes with WARC's personnel and farmers, adjustments were made to accommodate the interests of the

client and develop a more qualitative approach to testing. Currently, 116 farmers work for WARC, out of which 59% are male, 46% are between the ages of twenty and thirty, 61% are illiterate, and 84% are married. In terms of labor, they are divided into nine groups in the out grower/extension program, which comprise 77 out of the 116 farmers.

We split into two pairs and interviewed farmers individually, asking them first general questions, then doing the paper-based tests, and concluding with the phone-based trials. It is important to mention that we chose not to use focus groups because the answers tend to be affected by a collective bias, where the perception of one is affected by the opinions of others. On the contrary, the individual tests allowed us to evaluate each farmer's preferences, needs, and reactions, and after pooling the data together, identify trends and general patterns.

Changes to the Questionnaire

The original questionnaire was broadly divided into two parts: the first being questions that gauged information about the current situation among farmers and their challenges in the field, and the second part included more interactive questions like AB testing and showing actual examples of features on a mobile phone and asking them to use it. However, the survey instruments that were eventually finalized for the interviews for the March trip were changed in order to incorporate feedback from the preliminary meeting with the client in Tormabum. The conclusion of the meeting was to take a much more qualitative approach to the interviews and subsequent analysis. Since WARC intends to introduce a mobile platform, their goal was to understand how farmers, the ultimate users of the product, currently interact with technology. Therefore, some of the questions that were irrelevant to achieve the goal were removed. Also, after the first day of interviews, we decided to exclude additional questions based on feedback and responses from the first few farmers. The main changes made to the interview process are as follows:

- We realized soon enough that the farmers we were interviewing did not have much exposure to smartphones and showing them different features of sign-in pages and scrolling vs. tapping was not an effective way to understand their preferences. Hence, we did not ask about these features moving forward.
- We focused more on the audio/text/video question and their subsequent answers to the questions that followed.
- We also spent time asking the respondents to use a smartphone which had one of the researched apps. We recorded their interaction and their ability to navigate the app on their own. This proved to be a much better way of understanding their level of comfort.

Throughout the process, one team member noted their responses, and the other observed their behavior and interaction with the app prototypes. This provided an all-round understanding of the farmer's responses. Half of the interviews were conducted during the

morning (after the daily team meeting) and half during the afternoon. Each interview lasted no longer than 30-40 minutes.

After four days in Tormabum, we conducted 32 total interviews of WARC farmers, other affiliated WARC employees, and a handful of non-WARC farmers located in nearby villages. It is worth mentioning that WARC supervisors were targeted for testing, since they will likely be those who have the easiest access to technology and who might be best prepared and positioned to teach the rest of the farmers how to use the app. Finally, all interviews were conducted with consent and all answers were recorded on paper. After polled, all results are analyzed following the criteria explained in section X.

XII. Evaluation Plan for Results

Criteria of Data Presentation

By the end of our work in Tormabum, we had collectively interviewed a total of 32 farmers. The paper-based information was later transferred to a computer for ease of access. Based on the data that was gathered and the vision of WARC, we focused on the more qualitative aspects by discerning larger themes and patterns that came to light. Once interviews were finalized we had a debriefing session with WARC Group to discuss preliminary findings and potential next steps towards making an informed decision.

The meeting provided us with further guidelines on how to analyze the data that we had collected from the farmers. The emphasis on the qualitative aspect was reiterated and we discussed WARC's vision of the app. Given that most of the survey questions are qualitative and the relatively small sample size, we would not conduct inferential statistics, such as test of statistical significance, that give the probability that a claim arising from the data can be applied to the user population as a whole. However, the objective of understanding the underlying situation and apprehension of farmers was successfully met through rigorous qualitative methods. In addition to getting insights into the farmers' preferences on the content of the app through direct questions from the survey, we established a coding scheme to categorize the answers on a scale of 1 to 3 – 1 being the lowest in terms of ease of using a smartphone and 3 being the highest. Each respondent was assessed by the interviewer based on the farmer's perceived comfort in using the smartphone. This scale would be used to analyze any trends that can be discerned across the pool of respondents.

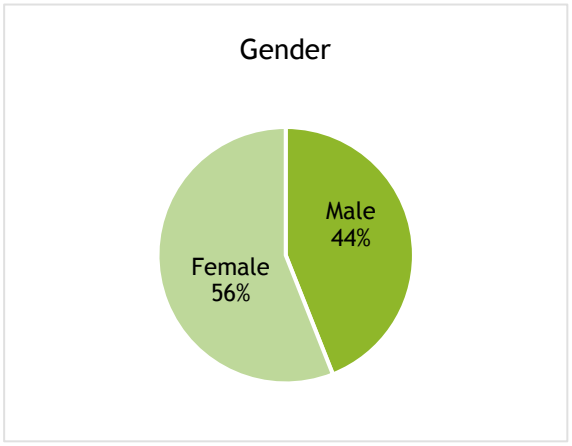
In addition to the results from the questionnaire and the qualitative analysis, we will also provide descriptions of relevant anecdotes that will help to better understand farmers' level of comfort with technology. This will guide any conclusions that can help identify potential opportunities and gaps in the context of introducing a smartphone app within the farming community.

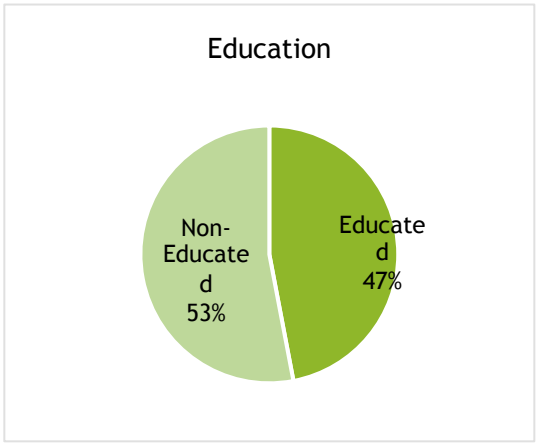
XIII. Results and Analysis

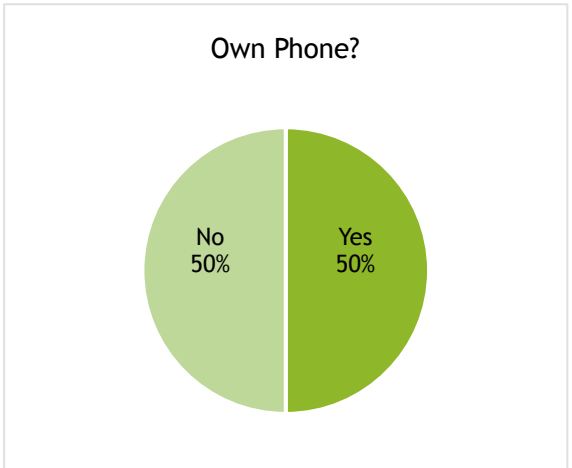
Respondent Demographics

During testing in March, we attempted to mirror the demographics of the larger community with our respondent group. For example, 84% of our respondents were either full-time or part-time farmers, and the remaining 16% of respondents pursued occupations connected to WARC's farming operation (such as carpenter, warehouse manager, cleaner, etc.). About 56% of the respondents were female, and 44% male. Of the respondents interviewed, 44% had received some form of education, while the remaining 56% had received no formal education. All of the respondents spoke Mende, and half were conversant in English. In terms of literacy, slightly under 50% could read either Mende or English. Exactly 50% of our respondents currently or previously owned a mobile phone. The majority of phones were SMS, but a handful of respondents with mobile phones had a basic smartphone model.

Figure 14: Respondent Demographics







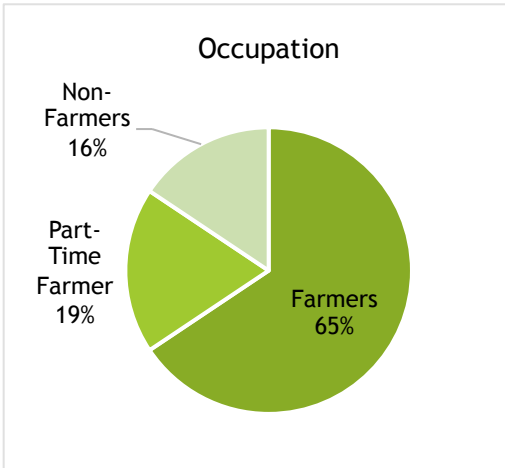


Figure 15: Key Findings during our March Trip

1. Video was the most popular mode of receiving information, but respondents were much more successful at retaining audio information.

a) Testing Process

During interviews, respondents were presented with three short statements of information, and asked to remember what they were shown. The intent was to see if there were any significant differences in information retention between the different modes of communication.

First, the respondent watched a thirty second video of a member of WARC's staff, in Mende, saying that the East African countries of Ethiopia, Kenya and Uganda had many mobile phones, and Kenya had the most mobile phones in East Africa. Second, the respondent listened to an audio clip, in Mende, where the same speaker mentioned South Africa grew a lot of corn, oranges and wheat, and corn was the most common crop grown in South Africa. Lastly, respondents who were literate were given a short (fictional) passage stating that green, yellow and blue are popular colors in Sierra Leone, and that a recent survey showed blue was the most popular color in Freetown, Sierra Leone. Following the exercise, respondents were asked which mode of communication they preferred to learn information. Later - approximately 10 minutes after this information was presented - the respondents were

asked about the East African country with the most cell phones, the most common crop in South Africa, and the most popular color in Freetown.

b) Outcomes

Perhaps surprisingly, there was a strong divergence between the respondents preferred mode of communication and the mode of communication that resulted in the highest retention of information. 65% of respondents preferred video for learning new information, compared to 19% preferring audio and 16% preferring text. Many of the interviewees stated that new content was easier to understand, remember and replicate when viewed over video.

Preferences notwithstanding, the respondent's retention of audio information was much stronger than either video or text. **94% of respondents were able to remember the audio clip's fact that corn was the most common crop grown in South Africa, whereas only 22% of the respondents could remember the video's claim that Kenya had the most cell phones in East Africa. Among those who could read, 67% were able to remember the text stating that blue was the most popular color in Freetown.**

Anecdotally, during one of our interviews with a man working in the garage, he held the speaker to his ear continuously in spite of reminding him that it was a video tutorial. At the beginning, when we gave him the phone to listen to the audio, he kept the phone to his ear and said "Hello", until our translator told him that he was not on a call and he had to listen to the audio.

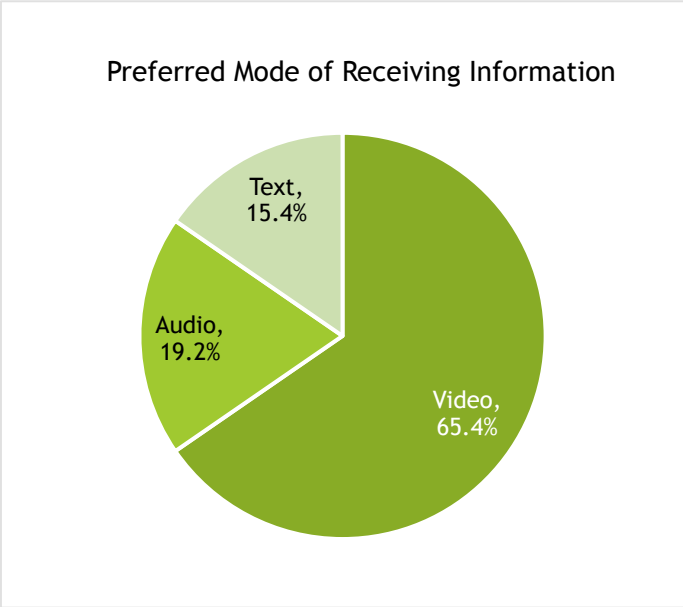
c) Conclusions

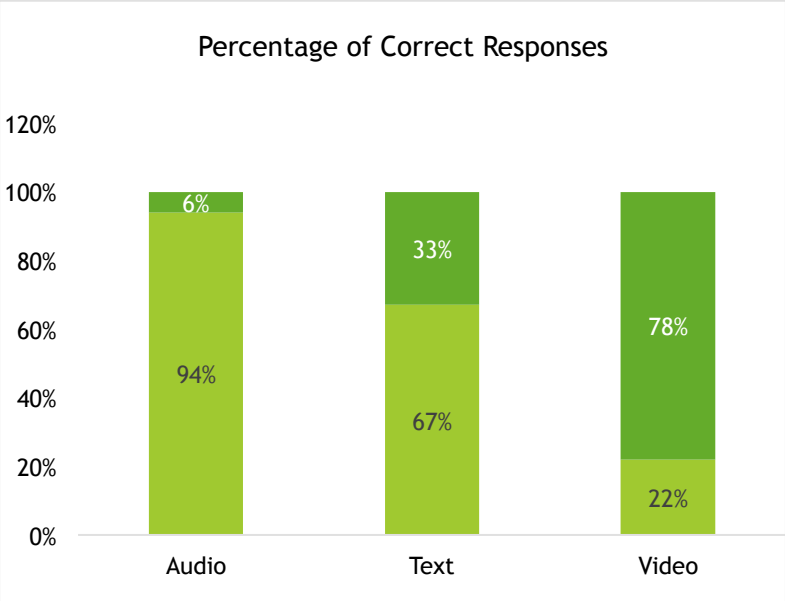
We believe this divergence between audio and video retention might be explained by two factors.

- First, one might conclude that questions pertaining to farming (such as the audio question) will resonate with, and be better retained by, farmers compared to names of East African countries. While this might have played a role, only one of our farmer respondents grew maize, while the rest were focused primarily on rice cultivation, and secondarily on peppers and cassava. If farmers were merely guessing the names of crops they were previously familiar with, we would have expected a higher incidence of incorrect audio guesses when asked the follow up question. Furthermore, all of the indications we received from our respondents suggested that they were familiar with the names of East African countries that were mentioned in the video.

- Perhaps another explanation is tied to pre-existence level of comfort with each mode of communication. For most of our respondents, the interview was the first time they were holding a smartphone and viewing video content on a phone, which likely posed some distractions. It was possible that many respondents were preoccupied with watching the speaker's movements rather than focusing on the exact content he was delivering. Audio, by contrast, is a mode of communication that nearly all of our respondents are well-versed with, by virtue of listening to radio on a daily basis. When presented with the audio information, of the respondents held the phone near their ears and listened closely.

Figure 16: Key Results of Learning Tests





2. Descriptive picture content is the most easily-understood representation of objects

a) Testing Process

Our team presented a number of paper-based visuals showing mock app screens and asking the respondents for their preference in terms of which options might be easiest to understand and remember in the context of a smartphone app. Our main takeaway was that picture-based content, and especially literal and realistic imagery, was strongly preferred to alternative displays of information (whether that be text, graphs, or representative imagery or infographics).

For example, we showed respondents two example pages of information, one with graphs, text and minimal imagery, and the other with text and photographs of farming activities. Not surprisingly, we found that 100% of the illiterate respondents preferred the image-heavy option, but we also found that 75% of literate respondents preferred the imagery representations over text.

b) Outcomes

Imagery was clearly preferred, and specifically realistic photos were preferred over other kinds of images. In a second question, we presented four representative images of pesticides, and asked which image would be easiest to navigate to if located on a farming app's menu if the respondent was looking to access pesticides. **The first was a photograph of a man spraying pesticides, the second was an infographic of a stick figure spraying pesticides, the third was a cartoon image of a pesticide bottle, and the fourth was the word "pesticide" in English text. 69% of respondents preferred the photo depiction of**

pesticides, followed by 16% for the infographic stick figure, 12% for the cartoon bottle drawing, and the remaining 3% for text.

Respondents overwhelming (74%) picked the two buttons with the text overlaid. While 93% of literate respondents picked the text options, an additional 56% of illiterate respondents also selected one of the two text buttons. When we asked the *illiterate* respondents why they preferred these text options, the vast majority answered that they could still sound out and understand the word(s) "help" and/or "ask," and that this text provided helpful context for them to understand and remember the purpose of the button.

c) Conclusions

We observed one notable caveat to the preference for images over text: it appears some basic, common English words are widely-understood by both literate and illiterate respondents, and our results indicate that a majority of both literate and illiterate respondents would prefer basic text, in addition to imagery, to provide them with helpful context. For example, we presented respondents with six different representations of a "support" button, and asked them which option would be easiest to recognize and understand if placed within a smartphone app. One option was a button with the word "Ask" overlaid, one was a button with the word "Help" overlaid, and the other four contained no text but rather images of a question mark (two different options), a phone with a question mark, and a basic red button.

3. There is a significant gap in smartphone "ease-of-use" between generations

a) Testing Process

Unsurprisingly, we observed a noticeable gap in the level of comfort and ease-of-use between the younger generations (40 and below) and older generations (above 40). To test whether this might be true, we observed each respondent using and exploring the smartphone given to him or her after requesting a task be performed. For example, we would show the respondent how to navigate to the camera and take a picture. We would then give the respondent the phone and ask him or her to take a photo for us. During this exercise, among others, we coded the observed level of the respondent's "ease of use" and comfortableness with the smartphone. Ease of use was marked in three levels, "1" (for no ease of use), "2" (for moderate ease of use), and "3" (for significant ease of use).

b) Outcomes

We found that respondents aged 40 and below averaged a score of "2.13" - suggesting a fairly moderate-to-high level of comfort with navigating a smartphone among the younger generations - whereas every respondent over 40 years old scored a "1" on this scale, without exception. A portion of this gap was explained by some of the younger respondents having currently or previously owned or used smartphones. **However, when past smartphone use was controlled for, respondents aged 40 and below still averaged a score of "1.88," which was nearly double that of the over-40 respondents (who averaged "1").**

Anecdotally, we observed a number of examples that furthered this point. During one interview with a middle-aged woman who was struggling to use the smartphone, she handed

the phone over to her teenage daughter who had been watching parts of the interview. The daughter, despite never having owned a smartphone or received any instructions on how to use the device, quickly navigated to the camera and scrolled through past photos and videos recorded on the device. The difference in observed levels of comfort using the smartphone between mother and daughter was striking.

c) Conclusions

The vast generational gap between respondents above the age of 40 and below the age of 40, was potentially due to differences in education levels and/or experience with and prominence of technology during their youth. We expect that some level of comfort and experience with technology can greatly help people more easily and effectively transition to using a technological tool, like a smartphone app.

4. Most respondents suggested a willingness to use smartphones, and a confidence to learn, if training is provided

a) Process

Based on conversation and observations during the testing period, we witnessed a substantial difference in comfort levels of technology use.

b) Outcomes

There was a clear difference among age groups in their pre-existing levels of comfort using a smartphone, but nearly all respondents across all ages groups expressed a willingness and confidence to use smartphones if provided with hands-on training. This point was explicitly mentioned by a handful of respondents, who stated that a couple weeks' of in-person training would allow them to feel more comfortable using a smartphone. After hearing this insight from several farmers, our interview groups asked subsequent respondents if they believed they would benefit from hands-on training if provided with a smartphone and relevant agriculture app. Most of the respondents, with the exception of a handful of younger respondents, indicated that they would benefit from this kind of training before being asked to use a smartphone app. Encouragingly, a handful of the younger and more highly-educated respondents expressed an interest in training their fellow community members on how to use an app, once trained themselves.

c) Conclusions

Using the observations and responses from interviewees, we were able to conclude that successful implementation will require hands-on training, as many of the farmers are not even very familiar with holding a smartphone or using apps. Much of this training could be provided by some of the younger, more educated members of the WARC community who have higher levels of comfort with smartphones.

5. Many respondents rely on community leaders or WARC staff as their first points-of-contact for help

a) Process

During the survey process, we asked respondents who they reached out to for assistance when experiencing an issue tied to farming or other work.

b) Outcomes

As expected, many of the respondents (34%) indicated they first contact an immediate family member for help. However, an even larger share of respondents (44%) indicated that they reach out to either their master farmer or village chief (22%), or WARC supervisors and staff (22%).

The method of contacting help was primarily "in-person," however phone contact was another popular method. Of the respondents who owned phones, nearly half (46%) indicated they use their phones as the primary means of communication when they need assistance in the field.

Additionally, it is important to emphasize that a majority of farmers expressed an interest in having some sort of "button help" in the app, which would allow them to contact an expert (or a member of the WARC personnel) in cases of emergency or when facing a particular problem. They believe that this type of personalized service would allow them to quickly and adequately respond, and thus avoid potential losses.

c) Conclusions

These results suggest that phones are a valued method to get real-time help, and that qualified expertise from a master farmer or WARC supervisor is often proactively sought out by farmers in the field. An app which can facilitate real-time contact between 1) farmers seeking assistance, and 2) the local expertise who provide relevant help, would likely be in high-demand from farmers with access to smartphones.

6. Weeding crops, pest mitigation and navigating weather are the most commonly-cited challenges currently faced by farmers in Tormabum

a) Process

To help us brainstorm the kinds of content that would be highly-valued by farmers, we first wanted to better understand the biggest challenges currently faced by farmers in Tormabum and the surrounding villages. We asked our respondents to tell us the biggest challenge they face while farming, and purposely left the answer choices open-ended.

b) Outcomes

We found that the farmers cited three major challenges – weeding crops, dealing with pests, and navigating weather fluctuations (such as heavy rains). **54% of the farmers we**

interviewed stated that effectively weeding their crops was the most difficult aspect of farming. Another **27% of the farmers we interviewed said that mitigating pests** in the field was their most significant challenge. Finally, **19% of the farmers we interviewed cited challenges tied to weather and heavy rains.**

c) Conclusions

By understanding the major challenges faced by rice farmers in Tormabum and the surrounding villages, WARC can tailor the future app's content and information to effectively address the issues that matter most to improving the yields and quality of life of local farmers.

7. Respondents provided a wide range of desired functions from a future smartphone app

a) Process

A primary goal of the WARC team was to gain insight into what features or attributes of an agricultural app the farmers would find most useful. In order to do this, we used visual and descriptive examples to offer options of functionalities of an app, and also solicited respondents' open-ended feedback. We also evaluated how respondents reacted to the question and observed what skills and activities the farmers cared most about.

b) Outcomes

Many respondents indicated they would gain value from the social and communication components of a smartphone farming app. However, there were a number of other functions that respondents expressed interest in. **Notably, 43% of respondents indicated they would be interested in receiving some form of farming tips or other real-time farming information from the app. 25% of respondents expressed interested in using an app for mobile banking, and another 16% expressed interest in gaining access to relevant farming equipment.**

However, a degree of caution is needed when evaluating this particular result, since we noticed that some of the farmers' responses may have been biased by the translators asking the questions in Mende - and weighting his or her preferences when suggesting options to respondents -which may have increased the prevalence of certain responses like mobile banking.

Anecdotally, when shown the smartphone app, a majority of the farmers were interested in accessing information on weather patterns and learning how to improve their farming techniques, particularly in dealing with pests and other common challenges.

c) Conclusions

Connecting the Reiss framework, described in section IX, to these results, it's clear an agriculture app - depending on the ultimate function(s) it serves - could satisfy any number of fundamental user desires, including Power, Independence, Social Contact and Saving. By

providing relevant information and resources to farmers, a smartphone app can empower users to improve yields and make better, more-informed decisions on their land. By facilitating communication between farmers and WARC or community leaders, the app would enable valuable social contact that leads to faster problem solving and improved coordination in the field. And mobile banking would allow users to more efficiently manage their finances, and perhaps even promote greater levels of saving when yields exceed consumption.

XIV. Recommendations

Recommendations for the Project

1. **We would recommend starting off the project with a mobile solution that uses SMS to provide localized weather information, crop information as well as market information in the short run,** due to the main barriers being poor internet connectivity, limited access to smartphones and expensive data usage requirements.

   - Reuters Market Light, a similar SMS service for farmers has successfully been used by over 1.3 million registered farmers in 17 Indian states. The SMS service can be slowly transformed into an app-based service in the long run.

2. **An alternative solution would be to develop a stand-alone app and setup a hardware device to serve as a portable hotspot tower that stores and transmits data to smartphones via Bluetooth,** so the system can function when there is no Internet connectivity at the WARC office or a place where all the farmers visit regularly.

   - Once the farmers connect to the app, the statistics can be stored on cloud servers. If the farmer is without Internet connectivity, the data is sent to the cloud server via a SMS. The cloud technology should be used to increase app functionality without increasing the size of the app.

3. **Push notifications should be sent to the farmers with information signaling the beginning of the planting season, reminding them to remove weeds, or informing them of new crop diseases and pests**. This is an easy way to transmit instant information since most farmers can easily access push notifications.

   - A drawback of push notifications is that it drains the mobile battery at a faster rate. Since electricity is scarce and expensive, charging stations can be set up at locations closer to the farms they work in or they would have to travel a long distance back home to charge their mobile phones. WARC can also provide the farmers with charging stations.

4. **To get the older users to get invested in the app, a gamified "points system" could be included in the app to reward farmers who are regularly using the app and implementing what they learn most effectively.**

- This would also help bring new users into using the app and increase the worker performance on the field. These points could be later exchanged for commodities such as seeds, fertilizers, etc.

5. **Apply a testing framework, like Nielsen's Heuristics, to ensure that in the app development process the issues of farmer literacy, culture, and context are taken into account.**

Future Testing Framework

One recommendation we can supply for any future testing, that will allow the app to adequately support the purpose of the project but also be accessible and appropriate for the farmers, is to use a simple testing framework, like Nielsen's Heuristics. We believe an anecdotal presentation of user experiences was most useful during the stage of app development and testing for WARC. However, we believe that for future testing and design, especially by a coder, the WARC term should use Nielsen's Heuristics as a possible guideline or framework. We believe that this framework will allow the WARC team and the coder to establish an understanding of cultural and societal context, understand farmer desires, and effectively test the compatibility of the app with farmers' everyday lives.

Figure 17: Nielsen's Heuristics Table

Heuristic	Description
Visibility of system status	The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
Match between system and the real world	The system should speak the users' language, with words, phrases, and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
User control and freedom	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialog. Supports undo and redo.
Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
Error prevention	Even better than a good error message is a careful design that prevents a problem from occurring in the first place.
Recognition rather than recall	Make objects, actions, and options visible. The user should not have to remember information from one part of the dialog to another. Instructions or use of the system should be visible or easily retrievable whenever appropriate.
Flexibility and efficiency of use	Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both the inexperienced and experienced users. Allow the users to tailor frequent actions.

Aesthetic and minimalist design	Dialogues should not contain information that is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
Help users recognize, diagnose, and recover from errors	Error messages should be expressed in plain language (no codes), precisely indicating the problem, and constructively suggesting a solution.
Help and documentation	Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focus on the user's task, list concrete steps to be carried out, and not be too large.

Recommendations for App Features

1. **The app framework should be exclusively based on 'skeuomorphism' which is the use of real images.**

   - Our survey showed that majority of the farmers do not read and even those who read argued that it was easier to understand and learn when they can see how things should be done with the help of real images rather than abstractions of reality. The usage of infographics or icons should be avoided since most of the farmers found it hard to relate to them or understand what they meant easily.

2. **If the use of words is necessary, use English or Creole.**

   - Most farmers who know Mende do not know how to write or read it, yet they can identify written words in English or Creole. As our interviews demonstrated, basic English text can even provide helpful context for both literate and illiterate farmers. In addition to the text, consider including an option to listen to the oral explanation in Mende.

3. **In order to navigate from one page to the other, use left and right arrows on the screen (clicking) instead of swiping left or swiping right as this is more intuitive. Other intuitive features include scrolling up and down.**

4. **Include a floating help button to appear on every screen of the app or alternatively only in the main menu.**

   - This is important because many farmers believed that it was essential to have someone to contact for technical assistance or in case of an emergency.

5. **Since most of the farmers don't keep a record of their harvest or only have a rough figure, an easily usable registry option can be included, where farmers can input their yields and keep track of both their consumption and sales.**

6. **We recommend using audio tutorials to teach better farming techniques and provide other relevant information on harvesting, weeding, use of fertilizers, etc.**

Video tutorials would only make sense if demonstrating physical activities in the field.

- Our survey showed that farmers proved to learn more easily through audio clips rather than text or videos. This might have a close correlation with the use of radios by the famers as a source of information.

- The usage of videos should be minimized or avoided as they require much higher data usage and faster internet speeds, both of which are challenging requirements in Tormabum and the surrounding villages.

7. **The smartphones for the farmers should be basic smartphones that are somewhat familiar and more common.**

   - These phones would have limited storage memory. Audio can more easily be downloaded and stored into the app (when it acts as a standalone app). Relevant gifs (loop video) or images can be used while the relevant audio tutorial runs in the background. More familiar and common phones also allow the farmers to ask community members for assistance.

8. **Include only the most relevant, essential information in the app.**

   - A clutter of information and imagery causes unnecessary confusion among farmers who have limited literacy and no prior experience using smartphones.

   - For instance, if the app includes information on seeds or fertilizers, use images of the seeds and fertilizers that they are familiar with; otherwise, they might not understand what the "icon" is intended to signal or what they are supposed to do with the information provided.

   - Since the perspectives of the farmers from 3-5 years ago are unlikely to remain relevant in the future, the app must be regularly updated over the long-term.

   - Farmers should be informed when updates are complete and should be trained on how to download and use the updated version. Constant feedback from farmers is essential to guarantee that the app remains relevant to their work and useful for WARC's purposes.

Recommendations for Implementation

1. **Conduct a pilot with a small group of young farmers who are more educated.**

   - They can act as "teachers" or "instructors" for the rest of the app users. For instance, the community teacher in the village of Largo (who is also a WARC employee) showed a lot of enthusiasm to learn and teach his community on how to use the app. They should also be a part of the training.

   - Additionally, consider conducting several weeks of training before rolling out the app. During the training, the benefits of using the app should be clearly explained to the farmers, and what they can personally gain from it. We observed that once

they were told how their own livelihoods would be improved, they expressed an interest in using it.

2. **Ensure for affordability, accessibility, and maintenance of smartphones.**

- One challenge is that a majority of farmers don't own a smartphone and have never used one. They would first have to be trained on the basic operations of a smartphone before teaching them what an app is and how to use the app.

- One of the main reasons why they don't own a smartphone or have not got a replacement after their old phone malfunctioned was because it was too expensive for them to afford the costs of recurring data fees and a replacement device.

- Additionally, most small rural villages in Sierra Leone don't have access to cellphone sale and maintenance points, and so they would have to travel to the bigger urban centers to replace or get their phones repaired. This evidently represents a prohibitive cost for most smallholder farmers.

- WARC should ensure that before or during the rollout of the app, each family should own at least one smartphone. This can be ensured by providing smartphones at subsidized prices by WARC— they do not have to be the newest or most advanced models; in fact, older models are probably more appropriate for farmers who have never before used a smartphone.

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XVI. Appendix

Appendix I. Survey questionnaire

NOTE: The following questionnaire was designed prior to the March trip. Questions were modified or added during the interviews (as described in the report), in order to obtain more feedback from interviewees.

Introduction: We are students from the United States of America helping WARC and learning about phone use in Tormabum. As you know, WARC is very interested in learning new ways to help farmers and understand how farmers use phones.

Name	
Sex	
Age	
Occupation	
If farmer, what do you farm?	
Literacy level / years of education	
Languages spoken	
Do you have a phone	
If no, do you have *access* to a phone?	
If yes, how long have you used a phone for?	

If yes, is it a smartphone?	

I. General Questions

Which activity would be most useful for you? Second most useful? Third most useful??	Answer
A. Farming tips B. Mobile banking C. Access to equipment and seed suppliers D. Access to buyers of your rice E. Weather data and forecasts F. Farming scheduling / task reminders	

Which of the below areas do you find the most difficult during the rice growing season?	Answer
A. Planting and harvesting rice correctly on time B. Accessing farming supplies and equipment C. Using equipment and supplies correctly D. Selling your rice E. Accessing / using your money F. Weather G. Accessing feed H. Labor I. Paying for inputs / services	

How do you know when to [fill in a step of rice farming process] ?	Answer

Do you change your farming activities? If yes, why would you change something? If you are not getting high yields, how would you get information to improve?	Answer

Do you keep a record of your yields per harvesting season? Do you count your yields?	Answer
Follow-up Question: Did you sell any of this rice? How much did you sell, for what price?	

What were your yields this past season? Was it more or less than last season?	Answer

Did you sell any of your rice from last season? How much did you sell? For what price?	Answer

Do you use any of the techniques you learned at the training? If yes, which ones? If no, why not?	Answer

What types of pests do you encounter? What do you do when there is a pest?	Answer

When you have a problem in your farm, who do you contact and how?	Answer

1. **Paper Prototypes**

Respondent questionnaire

Options (Choose one)	Answer
1. A (Diamond pattern) 2. B (Square pattern)	
1. A (Left menu bar) 2. B (Bottom menu bar)	
1. A (selection from 1) 2. B (selection from 2)	
_____ Infographic _____ Text _____ Bottle of pesticide _____ Image of spraying pesticide	

III. App Prototypes

Options (Rank in order of preference)	Answer
1. A (Scrolling down through one-page onboarding menu) 2. B (Clicking through multi-page onboarding menu)	

1. A (Receiving info via video) 2. B (Receiving info via audio) 3. C (Receiving info via on-screen text) 3. D (Receiving info via picture graphic)	
1. A Swipe-out menu 2. B Fixed bottom (or top) menu bar	
1. A Onboarding with intro text and username/password fields 2. B Onboarding without text, simply username/password fields	

IV. User experience questionnaire

1. Respondent's level of comfort with answering questions	Answer

2. Does s/he seem to be needing a lot of probing?	Answer

3. How long did it take to complete the survey?	Answer

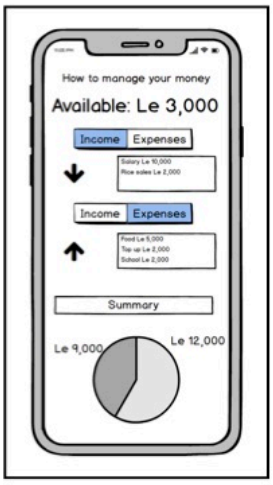
4. Which question was the most time-consuming? Why?	Answer

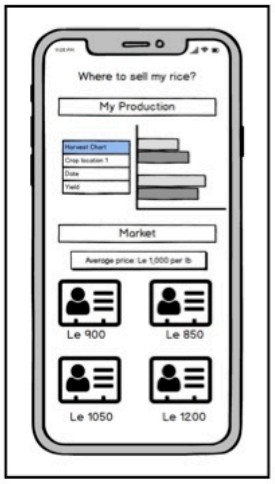
5. Which question was the most confusing for the respondent? Why?	Answer

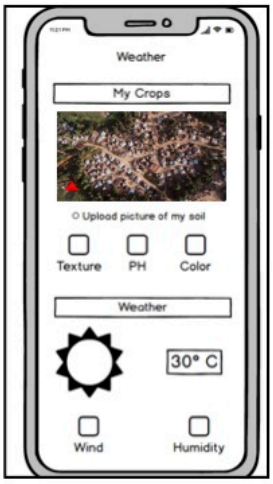
Observations:	
Which questions needed to be reworded?	
Why? How?	
Which questions did not give good feedback/confident answers? How can this be changed?	

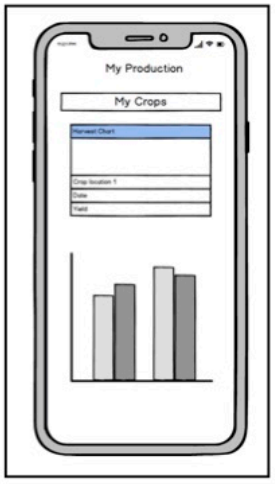
Appendix II. Paper-Based Prototypes

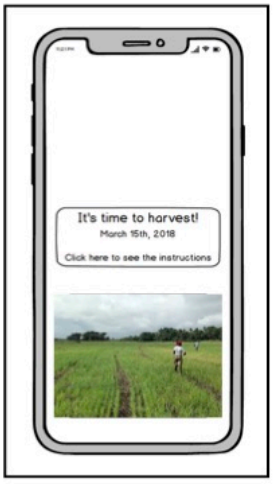

Farming tips
Tip 1
Tip 2
Tip 3
Learn more about farming here!


How to manage your money
Available: Le 3,000
Income
Expenses
Income
Expenses
Summary
Le 9,000
Le 12,000


Where to sell my rice?
My Production
Harvest Chart
Crop location 1
Date
Yield
Market
Average price: Le 1,000 per lb
Le 900
Le 850
Le 1050
Le 1200


Weather
My Crops
Upload picture of my soil
Texture
PH
Color
Weather
30° C
Wind
Humidity


My Production
My Crops
Harvest Chart
Crop location 1
Date
Yield


It's time to harvest!
March 15th, 2018
Click here to see the instructions