Food and Agriculture Organization of the United Nations

E-AGRICULTURE IN ACTION








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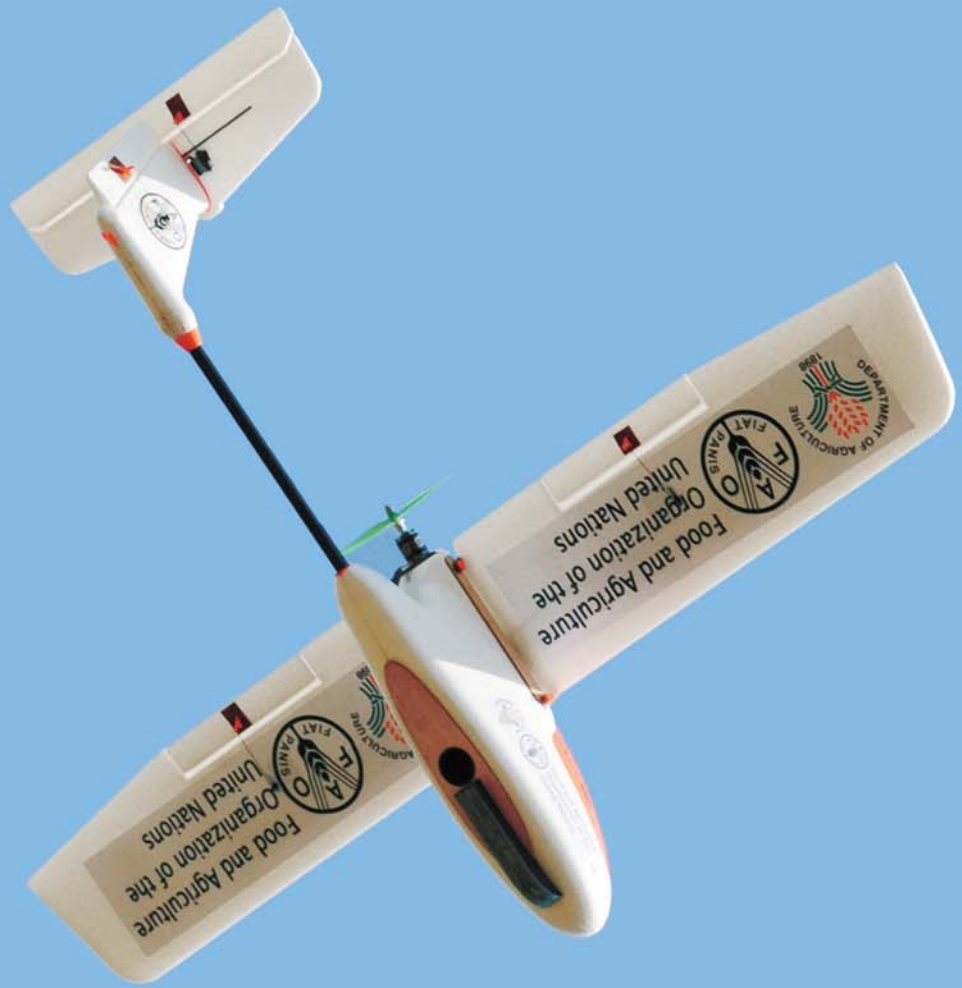

Preface

The role of information and communication technologies (ICTs) in agriculture has grown substantially in recent years in both scale and scope. Expanding broadband connectivity, increasing deployment of the "internet of things" (IoT), enhanced analytics, affordable devices and innovative applications are underpinning what we now call a digital society. This momentum provides stakeholders in the agriculture sector with opportunities to develop, adapt and apply these technologies as e-agriculture solutions. Taking advantage of ICT advancements and innovations is becoming more critical as we look for ways to offset some of the challenges faced by agriculture in a world where we must produce 60 percent more food by 2050. Applying e-agriculture solutions can transform the way we approach these challenges and act as an instrument of change in this sector and help us contribute to the achievement of the world's Sustainable Development Goals.

The G20 Agriculture Ministers' Declaration 2017 acknowledges the potential for, and increasing importance of, ICTs for improved food chain efficiency, productivity and sustainability of agriculture, improved animal husbandry practices and for adaptation and mitigation strategies in the context of climate change.

First published in (2015), "Success Stories on Information and Communication Technologies for Agriculture and Rural Development," has received wide acclaim, and has warranted this updated publication in order to further document case studies where innovative use of ICTs have helped people involved in agriculture and allied fields to become more effective and in many cases increase their productivity and income. The case study solutions covered in this compilation range from food production, supply chain management, advisory services, smart water management, and traceability to deployment of IoTs for sensing and analytics.

The articles are written by the respective authors and are entirely their own views. We have tried to maintain the original narrative style of each contributor. FAO or ITU does not promote or endorse any of the statements, comments and products mentioned in the articles. Thus this is an effort to simply share knowledge on the use of successful ICTs for agriculture initiatives and we expect that this compilation of case studies is read in that spirit.

This is second in a series of publications with the overall aim to promote the use of sustainable information and communication technologies for agriculture and rural development. We welcome contribution from ICT4Ag projects for our next compilation.

Acknowledgements

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‘Foodini’ – 3D Food Printing

Case study
A

HOW 3D FOOD PRINTING WILL AFFECT THE GLOBAL AGRIFOOD SECTOR

Overview

3D printing has already revolutionized industrial product development and is now poised to disrupt global manufacturing. As prices for 3D printers continue to drop, the technology is increasingly available to consumers.

3D printing of food is an emerging application; recent advances are delivering an assortment of products, from customized chocolate designs to pizza, pasta and hamburgers.

Natural Machines is a Barcelona-based 3D food printing company that leverages its innovation to promote healthy eating and reduce the consumption of processed foods high in sugar, fat, salt and preservatives.

Their device, ‘Foodini’, is the first Internet of Things (IoT)-connected 3D food printer that allows consumers to use fresh, wholesome ingredients to print a variety of labour-intensive homemade foods. When Foodini finishes printing dishes like pumpkin ravioli, spinach quiche, or whole-wheat crackers, they just need to be cooked.

Foodini is scheduled to hit the market in mid-2017, and Natural Machines is developing a version that will also cook food. The company has an ambitious goal: to put a Foodini in every kitchen, replicating the market penetration of the last breakthrough kitchen appliance, the microwave.

However, 3D food printing has much broader implications for the agrifood sector than the microwave. Foodini essentially acts as a mini food manufacturing plant in the kitchen. Its widespread commercial adoption could replace or transform food manufacturers and retailers in ways that would significantly reduce the 1.3 billion tonnes of food that is lost and wasted along the food value chain each year.

The IoT data collected by Foodini will create opportunities for food producers, retailers and manufacturers to optimize operations, while consumers will be able to customize meals according to their nutritional and dietary needs.

Figure A1: Foodini – 3D food printer

Context and challenge

In 2012, Emilio Sepúlveda, the CEO of Natural Machines, was helping friends launch a new vegan bakery in Barcelona. Business was booming; the bakery was receiving orders from as far away as London. Sending cakes to England was out of the question because shipping charges would be far more expensive than the costs of raw materials and production. Emilio had an idea: What if customers could access the recipe online and assemble cakes at their location using 3D printers? He enlisted two fellow engineers and Natural Machines was born.

Natural Machines created a 3D printer connected to the cloud that would let consumers choose what ingredients went into their cakes and sweets, rather than the manufacturers, while minimizing the complexity of assembly and precisely controlling ingredient quantities. This would also allow people with food intolerances or allergies to create cakes that complied with their food restrictions. The company originally planned on selling exclusively prepackaged ingredients in the food capsules that are inserted into Foodini.

Natural Machines' value proposition was enhanced by giving consumers more choice to use fresh, real ingredients for a wide range of foods. Lynette Kucsma, Co-founder and Chief Marketing Officer, explains that "rather than just being a cake and sweets machine, we asked ourselves, what if it printed savory foods as well? Rather than forcing consumers to always buy pre-packaged food capsules, what if we opened the system and allowed people to load their own fresh ingredients? This would massively expand the range and variation of recipes that people could make, based on individual preferences."

Foodini ships with five refillable stainless steel food capsules. Consumers choose a recipe from the touchscreen on the device; fill the capsules with freshly prepared food, and the recipe prints. Users can share recipes and access IoT data harvested from the device's sensors on Foodini's 'Community' platform online. Third parties can use the open platform to develop apps for their specific needs, like integration with wearable technology for diet and nutrition.

Natural Machines' confidence in the wide commercial acceptance of Foodini corresponds with current trends in the smart kitchen appliance market. According to a 2016 report from market researchers at Technavio in London, "the global smart kitchen market is expected to exceed USD 7 billion by 2020, growing at a Compound Annual Growth Rate (CAGR) of over 63% during the forecast period. Rapid advances in technology (especially IoT devices) and a strong focus on R&D will help reduce costs of smart kitchen appliances, thus driving the value of these products in terms of total cost of ownership."[1]

© Natural Machines

Figure A2: Printed by Foodini: whole wheat 'goldfish crackers'

[1] According to the market research analysts Technavio's latest report: http://www.prnewswire.com/news-releases/global-smart-kitchen-market-2016-2020-300227927.html

Foodini is being developed with input from potential partners and end users, including food manufacturers, retailers, nutritional supplement companies, chefs and home cooks.

The specific impacts of a high market penetration of Foodini have become clearer thanks to these alliances. A recurring theme is how actors along the food value chain will use the innovation to reduce food loss and waste. Other priorities for stakeholders include using the technology to improve nutrition, optimize primary production and boost environmental sustainability.

Benefits for stakeholders, partners and end users

Food producers

Farmers on the Foodini network will be able to access IoT metadata to analyse what people are eating, as well as where, when and how much. These data are aggregate and anonymous, and can only be collected with opt-in from the user.

Primary producers can identify regions with demand for their current crops, or plant crops that are in demand. Independent farmers trying to compete in the consolidated food commodity markets can adapt their operations to serve growing high-value niche markets, such as organic, and heritage grains and produce, etc.

Access to the Foodini platform's data will provide a link between primary producers and other actors along the value chain that does not exist today. The opportunity for farmers to bypass distribution brands and sell directly to manufacturers or retailers is spurring interest in Foodini at the primary production level.

Buyers downstream, with comprehensive information on primary producers, can source ingredients directly from farmers according to their evolving requirements on price, type of crop or market trends like the farm-to-table movement.

Natural Machines is also developing innovative packaging and tracking techniques for their capsules in the hopes of leveraging IoT data to create new business models that will help primary producers partner with actors upstream in the food value chain. Providing an online platform that lets farmers circumvent intermediaries and connect directly to restaurants, food retailers, and consumers will help mitigate food losses occurring at postharvest and processing levels, which account for 40 percent of all food losses in developing countries.[2]

Food manufacturers

Industrial food manufacturers are facing growing consumer and regulatory pressure to reduce the 'big three' additives in processed food – salt, sugar and fat – which also act as preservatives and mask bad flavours. Several multinational food manufacturers are using Foodini to test recipes of their flagship products with reduced salt, sugar, fat and preservatives.

Natural Machines has partnered with food manufacturing market leaders to improve packaging processes and materials for prefilled capsules that provide ingredients with the longest possible shelf life without the need for additives or preservatives. Identifying and using the most functional recyclable materials is also a shared priority for Natural Machines and the industry.

In the future, these conglomerates want to be able to sell their products directly to end users online. Foodini can offer consumers fresh-made versions of processed food brands adapted to

[2] Food and Agriculture Organization of the United Nations (FAO): *Global initiative on food loss and waste reduction* http://www.fao.org/save-food/resources/keyfindings/en/

individualized dietary, flavour and nutritional needs. Online sales will open the door to business-to-consumer (B2C) business models for manufacturers, sidestepping retailers entirely. According to FAO's Global Initiative on Food Loss and Waste Reduction, more than 40 percent of losses happen at the retail and consumer levels in industrialized countries.[3]

Foodini's IoT data will give manufacturers access to retail and customer usage and sales trends. Future features could automate B2C transactions or sales to retailers based on prearranged parameters and real time inventory tracking.

Furthermore, large multinationals like Nestlé and Pepsi are launching ambitious corporate social responsibility programmes whose goals for sustainability, development and nutrition dovetail with the expected benefits of the Natural Machines technology.

Food retailers

The supermarket industry is mature, with large, established and often multinational market leaders. Continued consolidation and a focus on organic and natural products are the major trends that currently dominate in the industry, according to a 2015 report by the consulting firm Market Realist.[4]

Both supermarkets and high-end food retailers are interested in stocking 'fresh-filled' Foodini capsules. The retailers would fill recyclable capsules with food they prepare daily in their stores, and stock them in their refrigerated sections (a customer could purchase an 'organic lasagne pack' available in several portion sizes, for example). As the capsules would be filled with freshly prepared food, they would have a shelf life of around three days to a week in the customer's refrigerator after purchase. At the higher-end, retailers have expressed interest in setting up delicatessen counters and cooks for made-to-order refills of the steel capsules that customers bring to the store, which will help reduce packaging waste.

Numerous hospitality sector companies have contacted Natural Machines to express their interest in buying Foodini: from in-flight caterers to international hotel chains and large amusement parks. Customization, repeatability and automation are features that attract these users.

Retailers, especially in industrialized countries, are increasingly finding themselves compelled by consumers, non-government organizations (NGOs) and governments to take action against food waste. A 2016 French law now prohibits supermarkets from throwing out or destroying unsold food, instead requiring them to donate the items to food banks or charity. UK retailers maintain a voluntary monitoring initiative called the Waste and Resources Action Programme (WRAP) that tracks retail and household waste. Annual figures from WRAP indicate that a total of 15 million tonnes of food are discarded annually in the UK, with retailers and households contributing to waste equally. WRAP estimates that 4 tonnes of this food are edible when discarded.[5]

IoT data will prove crucial for retailers as they will potentially be able to access data from both suppliers and customers of Foodini's prefilled capsules and fresh-filled capsule ingredients. Processes such as purchasing, inventory management, discount pricing and volume selling could be optimized and automated to reduce waste without losing revenue.

Nutrition and pharmaceutical companies

Various multinational nutrition and pharmaceutical companies have reached out to Natural Machines to explore the development of nutritional

[3] http://www .fao.org/save-food/resources/keyfindings/en/
[4] http://marketrealist.com/2015/10/snapshot-krogers-business-financial-performance/
[5] http://www.wrap.org.uk/food-waste-reduction

supplements or medicines that can be added to food using 3D printing.

Foodini's precision measurements, customization capacities and versatility appeal to stakeholders in this sector. Nutrient powders can be loaded into an empty capsule, along with up to four other capsules for regular meals (a veggie burger for lunch, for example). Consumers can enter the personalized quantities and types of nutrients into Foodini's cloud-connected user interface, and the printer layers the powder into the meals as they are being assembled.

Big data will propel innovation in this sector as well, granting nutrient providers, patients and doctors the tools to start dialogues that could save lives. Medical professionals can optimize dosages based on precise measurements of nutrients, times of ingestion and types of food ingested simultaneously, capitalizing on the anonymous, aggregate information of other patients with similar conditions. Nutrition companies will use this feedback loop to optimize their products.

Professional kitchens

Chefs are eager to outsource repetitive preparation tasks and want to create intricate designs not possible by hand. Natural Machines relies on professional chefs as key partners in the commercialization of Foodini. While the company's long-term commercial objectives target the home kitchen user, professional kitchens have proven to be reliable ambassadors for new food technology. In the past, chefs have successfully demonstrated appliances such as microwaves and food processors to consumers, which consequently made their way into people's kitchens.

In an interview with the BBC, Paco Perez, consultant chef of the Michelin-starred restaurant La Enoteca in Barcelona explained the attraction of innovation in today's professional kitchen: "In its day, traditional food was the avant-garde. The people who cooked it would use a blender, or a microwave, an oven, a heat lamp… You see, tradition is innovation – and always has been. Moving forwards, technology will always be present. Creativity is shaped by what technology can do."[6]

Foodini is currently being validated at La Enoteca and other Michelin-starred restaurants in Barcelona and other European cities.

As Ms Kucsma explains, Natural Machines is targeting the professional food market first, "to prove to people that, yes, it's safe to eat, it's fun to eat, it's real fresh food. Once you eat it in a restaurant, it's not far of a jump to bring it home and print it yourself."

Home users

People may disagree on what constitutes a healthy diet, but most are aware that eating too much highly processed prepackaged food is not healthy. By using Foodini, consumers can make fresh, homemade, and healthy versions of the processed foods that they buy now out of convenience and for economic reasons.

Foodini automates the time-consuming steps that often deter people from making home-cooked meals out of fresh ingredients. A good example is ravioli (or dumplings). Rolling out the dough to a thin layer, adding the filling, adding the top layer of dough, and then cutting it to size takes time. Simply load the dough and fillings into Foodini, and the device will print individual raviolis. The 3D printing of food – in this case, creating a layer of pasta, a layer of filling and covering it with a layer of pasta again – is assembling the ravioli. The process is identical to what a home cook would do by hand, except Foodini automates it. The user does not have to do all the work manually, meaning less mess in the kitchen and more time to do other things.

[6] http://www.bbc.com/news/business-35631265

© Natural Machines

Figure A3: Pizza printed by Foodini

A taste test using Foodini was conducted in 2015 in one of the largest US supermarket chains. After the customers were informed that Foodini prints real, fresh food, 90 percent of them said that they would eat food prepared by Foodini. Natural Machines expects the price of Foodini to drop significantly as production is scaled up and they are able to customize some of the off-the-shelf components they are currently using. The first commercial microwaves cost US$3 000 in today's dollars when they were introduced; they can be bought for less than US$100 today. Flat screen TVs represent a more recent example of this phenomenon.

Foodini offers added value to home kitchen users with specific nutritional needs and dietary preferences. The device tracks, monitors and uses specific ingredients with exceptional precision through its cloud-based user platform. Users can fill the empty steel canisters themselves, and, if they like, upload the names and quantities of the ingredients into their Foodini account online, which will automatically monitor and track the ingredients in their diets, whether it is glucose, gluten or ground pork. Users who can only eat a certain amount of sugar at a time will be able to set Foodini to stop printing a chocolate dessert when it reaches exactly 150 calories, for example.

Similarly, consumers with allergies will be able to customize their meals to ensure that no allergens are present.

In line with the growing trend of consumers who want to know where their food comes from, Natural Machines presents a novel solution. With the integration of identification technology in the food capsules, Natural Machines will create a cloud-based database in which the contents of the capsules are tracked from farmer to consumer. Consumers will be able to see when and where their food was cultivated, harvested, packaged and delivered, ensuring traceability.

Children especially enjoy Foodini's design element which parents can use to ensure a more balanced diet. While a child might not eat a plate of sautéed or boiled spinach, Natural Machines has found, in tests with home cooks, that kids are happy to eat 'spinach quiche dinosaurs' (Figure 4A).

© Natural Machines

Figure A4: 'Spinach quiche dinosaurs' printed by Foodini

Food security and social impact

Food security, one of the world's greatest challenges, "exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 2015). With its 3D food printers, Natural Machines aims to address all these issues.

First and foremost, Natural Machines developed Foodini to help more people to eat fresh, healthy food. If that is not readily available, Foodini can provide the most nutritious food possible, meeting dietary needs and catering to customized food preferences. The new systems that Natural Machines are developing to prefill food capsules require no preservatives or cooling systems. The ability to minutely control specific nutrients will help to ensure that individual nutritional needs are met.

Finally, there is a strong gender component to the Foodini concept. In many parts of the world, women still assume the traditional role of caregivers at home. Foodini is easy to use and can be used by any member of the family, providing an opportunity to increase the involvement of men in the home, and will, at the very least, facilitate the work of women.

How it works

Technology

The Natural Machines device uses conventional 3D printing technology – which is to say that a design from a digital file is produced by laying down successive layers of material until the entire object is created – but applies it to food. Foodini also uses computer vision technology to create and record designs, with a scanning function that allows users to create and upload their own designs. Next-generation identification and tracking technology integrated on the capsules lets users ensure traceability along the food value chain. The Natural Machines cloud platform manages the IoT data coming from the various sensors in the Foodini devices worldwide, as well as from producers, retailers and manufacturers who join the Foodini network (which is to say that at some point they register their participation in the production or distribution of Foodini food capsules or their ingredients).

Foodini comes connected to the Foodini 'Community' cloud platform with plug and play access to recipes and IoT data.

Natural Machines started developing Foodini in 2012. It is now factory-ready and will start shipping to professional kitchen users in 2017. Each unit comes with the five empty stainless steel capsules that users can fill with fresh ingredients. The capsules have twist-off nozzles that are easy to clean. Nozzles are available in different sizes to accommodate the wide variety of food and food textures the machine can print.

The user selects the recipes and designs, puts in the required ingredients and printing begins. Although Foodini does not cook food, it can heat ingredients in their capsules. Natural Machines is already working on its cooking version, which they believe will be the tipping point to take the technology mainstream.

Foodini can function as a standalone tool delivering value even when not connected to the network or when others are not on the network. Using the 'Foodini Creator' (Figure A5), the custom-built easy-to-use software for users to make their own 3D prints, Natural Machines has removed the barrier of creating content and simplified the creation process, enabling users to promote the technology.

Foodini Creator is an easy way to create prints and recipes. The company is integrating as many creation widgets as they need to in order to make the user experience easy and interesting. Early users can easily create content that will ultimately be a part of the network. For example, with Foodini Creator chefs can create recipes for the 3D printing of foods and develop full 3D printed recipes. They are not limited to a library of shapes or recipes; they can create their own prints from scratch.

Summary of system components and dimensions

Users will be able to browse the network and content without having an account or Foodini, and a large amount of these users will share that content via other networks, not requiring user-generated content on the network from the start but instead riding on top of network effects from others. Users without accounts will have limited access to the network. For example, they can browse recipes and share prints, but they cannot rate recipes if they did not print them. When users get a Foodini and a network account, they gain additional access and features. Natural Machines is focusing on setting up the network to allow for in-network virality (rating recipes, liking recipes, customizing and resharing recipes, etc.) in addition to out-of-network sharing (Facebook, Twitter, Pinterest, Instagram, etc.) to create viral growth.

Natural Machines uses big data analytics to manage information received from stakeholders along the value chain and will make the information available to each stakeholder based on their needs and resources. With the broad commercialization of Foodini, the company will be uniquely positioned to leverage big data to disseminate relevant information to stakeholders who can use it most effectively to reduce food waste and loss, and add value along the food value chain.

Scope for scaling up

Natural Machines has been working with a well-known consumer electronics manufacturer since the design of the first prototype, streamlining the industrial design process and ensuring a reliable supply chain for components and a smooth scale up in line with the company's go-to-market plan.

GENERAL ASPECTS

1/ Dimensions machine

Width	Height	Depth
45.82 cm	43 cm	43 cm
18.03 in	16.92 in	16.92 in

2/ Printing volume

Tray Diameter	Max. Height
27.5 cm	11.95 cm
10.82 in	4.7 in

3/ Weight

15 kg
33 ibs 1 oz

4/ 10" interactive display

5/ 5 capsules

6/ Rotating base

7/ Capsule bay heater

80 ºC
176 ºF

8/ Maximum food volume

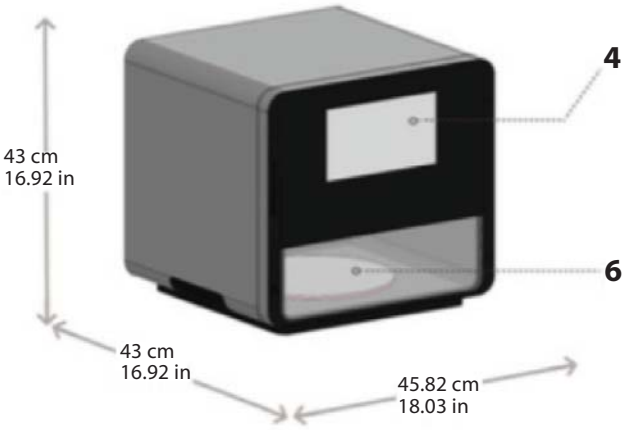
Each capsule
123 ml
4.16 oz

5 capsules
615 ml
20.79 oz

9/ Power supply 110V-220 V

10/ Max power consumtion 300 W

- Powered by Android
- Connected to Internet through WiFi (not necessary for all operation modes)
- Multiple user profiles possible in every device
- Durability: tested for minimum 2 years, 12 hours/day working life
- Certifications regarding safety, sanitation, etc.
- Very easy to clean: only capsules and dish in contact with food
- No maintenance required
- Remote assistance possible through embedded cameras
- Possible to post videos and pictures of food being produced on social networks directly from the device



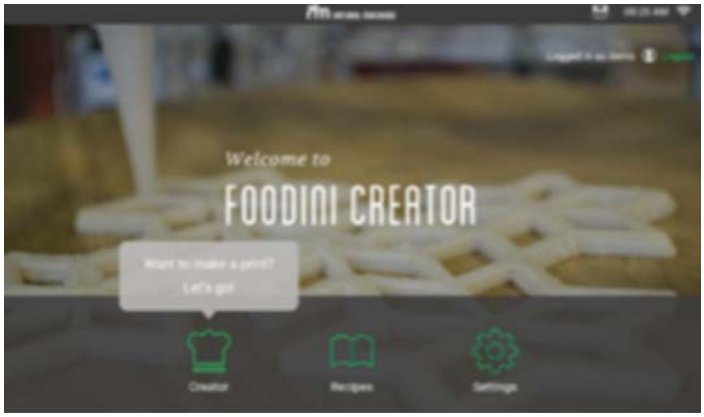


Figure A5: Foodini Creator

Looking ahead – the potential for 3D food printers to reduce food waste in the smart kitchen and beyond

Kitchens are becoming smarter with the integration of IoT-connected devices like refrigerators and ovens. Natural Machines is tapping into this trend, with Foodini equipped to play an integral part in reducing food waste in homes. Foodini lets consumers print what they want to eat and nothing more. There is no need to buy packages of premade/processed food with four servings for a family of three. The extra serving will just get thrown away or lead to overeating.

As kitchen appliances become more intelligent, they will communicate with each other and Foodini. If there is fresh spinach at the back of the refrigerator that will lose freshness in a day or two, the refrigerator can 'tell' Foodini to make recipe recommendations to encourage the household to use it immediately so that the spinach does not spoil and go to waste.

In a 2016 report, Reducing Waste through Social Innovation,[7] the European Commission identified the most common causes of food waste. Foodini has the potential to address each of these causes and reduce food waste from primary production to the end consumer:

- *Insufficient shopping and meal planning and promotions like 'buy one get one free' leading to too much food being purchased or prepared. Misunderstandings about the meaning of 'best before' and 'use by date labels leading to edible foods being thrown away*
  - Foodini can help families plan for meals based on usage and ingredient data that are recorded and managed by the Natural Machines IoT platform in the cloud, and can be shared with other 'smart' kitchen appliances. Dietary and nutritional needs will be addressed while food waste is reduced.
- *Standardized portion sizes in restaurants and canteens*
  - Customization is one of the features of Foodini that restaurateurs who have validated the device point to as significantly beneficial. The technology presents an opportunity for consumers – if they so desire – to share their dietary and nutritional 'profiles' with restaurants, which can design individualized plates for each diner based on these data.
- *Difficulty in anticipating the number of customers (a problem for catering services)*
  - Foodini prints the amount of food needed in the moment, and nothing more. Caterers will be able to save reduce waste by only printing what is needed; leftover ingredients can be saved or repurposed for other events.
- *Stock management issues for manufacturers and retailers*
- *High quality standards (e.g. for produce sold at retail)*
- *Overproduction or lack of demand for certain products at certain times of the year; product and packaging damage (farmers and food manufacturing)*
- *Inadequate storage/transport at all stages of the food chain*
- *Underlying all these problems is an overall lack of awareness, by many actors, of the sheer scale of the problem and the benefits that come from reducing food waste*

IoT data collected on the Natural Machines cloud platform will empower stakeholders to optimize food production and reduce food waste identified in the points above. Supply can be matched with demand in real time. Resources can be more

[7] http://www.eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf

effectively allocated to produce, package, distribute, prepare and consume food in response to constantly changing realities on the ground.

The ability to leverage information derived along the entire food value chain, from primary producer to consumer, represents the truly disruptive potential of Foodini in the agrifood sector.

For more information

Lynette Kucsma
E-mail: lynette@naturalmachines.com

GoviMithuru

Case study
B

KNOWLEDGE SUPPORT TO SRI LANKAN FARMERS THROUGH MOBILE ICT

Objective

The GoviMithuru mAgri service aims to provide a platform through which farmers can conveniently and cost effectively obtain information and connect with local farming communities and agricultural service providers for fast learning of good agriculture practices, sharing of knowledge and achieving better market access. Each stage of agricultural production requires a number of specific actions or decisions by the farmer (Mittal et al. 2010), which eventually determine the productivity and profitability of the farming operation. Along with productivity, quality of family nutrition and health also critically depends on information availability, such as nutritional value of crops, preventive health and hygiene practices, women/child nutrition and so forth at the farm level. However availability of good quality information at the farm level is a major constraint (Glendenning et al. 2010) and incurs significant cost (de Silva and Ratnadiwakara 2009), which impedes farmers' opportunities to learn about and adopt new technologies. Through the GoviMithuru service, this constraint is being addressed via innovative application of information and communications technology (ICT), which will not only solve the problem of information asymmetry at the farming level, but will also supplement and complement the conventional extension system by maximizing its reach and establishing better connectivity with farming communities.

GoviMithuru factsheet:

- Implementing agency: Dialog Axiata
- Donor: GSMA Development Fund/DFID
- Name of project: GoviMithuru
- Project Duration:
- Start: 01/05/2014
- End: 31/05/2017
- Grant awarded: October 2014
- Project Location: Sri Lanka
- Partners: Centre for Agriculture and Biosciences International (CABI) South Asia

Geographical coverage

In its initial stage, the service aims at addressing the needs of non-plantation and domestic food crop farms (e.g. paddy, maize, soybean, vegetable, perennial crops and other food grains) and dairy farms. Hence the targeted geographical coverage of the service is the entire island. However, paddy being the most significant domestic food crop, the service has been launched in the major paddy production areas; i.e. the north-central and north-western provinces.

Introduction

Context

Agriculture employs the second largest share of Sri Lanka's workforce, yet accounts for only about 11 percent of the country's gross domestic product (GDP).

The reasons identified for this low productivity are numerous and one major contributor is information and knowledge asymmetry (de Silva and Ratnadiwakara 2009). Such knowledge gaps lead to weak market linkages and limit adoption of available technologies and management practices. Further, the lack of coordination along the agricultural value chain from farm inputs to food processing increases the cost of production and lowers revenue for farmers.

Smallholder farmers in Sri Lanka fall into the lower-middle income category (Lokanathan and Kapugama 2012) and further among employed women about 31.8 percent was in agriculture sector and 26.7 percent for males (Sri Lanka Labour Force Statistics, 2016)[8]. More than 70 percent of rural women are involved in subsistence production and women have extensive workloads with dual responsibility for farm and household production (FAO 2005).

Although smallholder farmers spend most of their income on food (Dissanayake et al. 2011), malnutrition is a major health and social problem among rural farming populations (FAO 2005). This signals the need to improve nutrition literacy among farming families.

Hence, it is no longer sufficient for the agricultural community to focus singly on staple food production as the primary goal; there is an urgent need for farmers to pay attention to producing enough food of high nutritional quality and diversity thereby insuring healthy and productive lives. Agriculture should become a primary intervention tool if 'hidden hunger and poverty' are to be eliminated in sustainable ways.

Challenge

Development of an information-based decision-making agricultural system, which will enable farmers to access information economically, on demand, at the right time and in a localized format is essential. The system should offer a communication network to facilitate information flow between farmers and other actors in the value chain such as agribusiness, public sector extension service providers, policy-makers and researchers.

Response

Development of a simple voice telephony-based system using Interactive Voice Response (IVR) technology, which will enable farmers to interact with the system in their local language and will not need data connectivity or smartphones to operate is the solution. The frontend system is linked with various web-based management and analytics applications at the backend for designing, managing and analysing information flow and data.

About the initiative

GoviMithuru is an IVR-based agriculture information service, where farmers can register with relevant information and then get periodical push information (alerts) or can dial the IVR to listen to current advisories on agriculture, nutrition and preventive health care, tailor-made to their profiles. CABI's Direct2Farm agriculture knowledge management system backstops the IVR system with content developed by a team of subject matter experts from the Department of Agriculture (DoA) Sri Lanka and CABI in the form of mobile ready messages and factsheets.

Outcome

The GoviMithuru service enables farmers to better network with their local farming community while enabling access to local extension services using their mobile phones. Farmers can stay better informed regarding all the services available to them through the extension officer who is connected through the platform to the upper levels of the government agriculture information/service structure. Furthermore, during the cropping cycle, when farmers face problems regarding seed selection, pest problems and climatic conditions among other issues, they get constant support from the service in terms of periodic alerts (push messages) and an advisory message library (pull messages) which provides various best practices and tips. The service platform also enables farmers to subscribe to agribusinesses through their mobile phones and be constantly updated regarding the demand and the buying prices for agricultural produce. Farmers can similarly communicate their supply information (variety, quantity, selling price), which reduces the information gap in the value chain allowing farmers to make optimal selling decisions.

[8] www.statistics.gov.lk/samplesurvey/LFS_Q1_Bulletin_WEB_2016_final.pdf

Stakeholders and partners

The key stakeholders (Figure B1) in the GoviMithuru project are:

- Dialog Axiata PLC, Sri Lanka: Implementation agency;
- The Department of Agriculture, Sri Lanka (DoA): Subject-matter expert and content validation agency, agriculture; and
- CABI South Asia-India: Local content provider (LCP) and content quality assurance agency.

The GoviMithuru project is funded by the GSMA Development Fund from a global funding initiative on nutrition-sensitive agriculture established by UK Aid (Department for International Development [DFID] UK) for promoting nutrition-sensitive agriculture in 14 countries in Africa and Asia. The Centre for Agriculture and Bioscience International (CABI) takes the lead as a global content partner (GCP) of a consortium consisting of the Global Alliance for Improved Nutrition (GAIN), Oxfam GB, the International Livestock Research Institute (ILRI) and the British Medical Journal (BMJ) for this project.

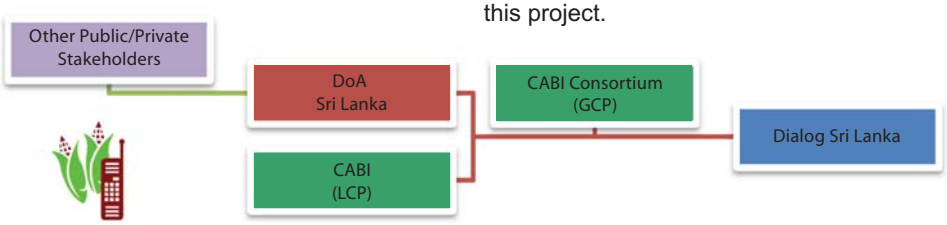


Figure B1: GoviMithuru Service

Methodological approach

Design

The GoviMithuru mAgri product was designed using human centric design (HCD) principles (inspiration-ideation-iteration-implementation). The design process was divided into two concurrent streams of activities led by CABI and the Dialog team respectively.

- Content design " led by CABI and the DoA
  - Landscape analysis of the agriculture and nutrition status of Sri Lanka. (Inspiration);
  - Based upon the landscape analysis, development of a content framework for the service. (Ideation);
  - Content framework vetted by key stakeholders that include agricultural extension, research and farmers' organizations etc. (Iteration-Implementation); and
  - Based upon the accepted content framework, development of a content development guide, content quality assurance (QC) guide and content development team (Implementation).
- Service design – led by Dialog Telecom
  - Investigative field study of target user groups (e.g. farmers, extension workers, farmers' organizations, agribusinesses etc.) to understand the current process (how they work at the moment), constraints (the bottlenecks or improvement areas) and need (what is expected as a solution). (Inspiration);
  - Based upon the landscape analysis, content framework and field investigation study, development of service prototypes. (Ideation);

Figure B2: Human centric design principles

– User testing of the prototypes. (Iteration-Implementation); and
– Based on user-testing results, development of a minimal viable product (MVP).

Implementation

Project team

The GoviMithuru project is managed by two teams (Figure B3); the implementation team from Dialog, backstopped by members from the GSMA Development Fund and Frog Design (for product development). The local content partner team is managed by CABI's Sri Lanka project office in collaboration with the Directorate of Information and Communication, DoA, Sri Lanka.

The local CABI team consists of the project manager, based in Kandy, Sri Lanka, the content manager, based in New Delhi, India, subject-matter experts from the DoA and in-country nutrition experts. CABI's Global Directorate on Mobile in Agriculture and the Global Content Partner Consortium support the local CABI team.

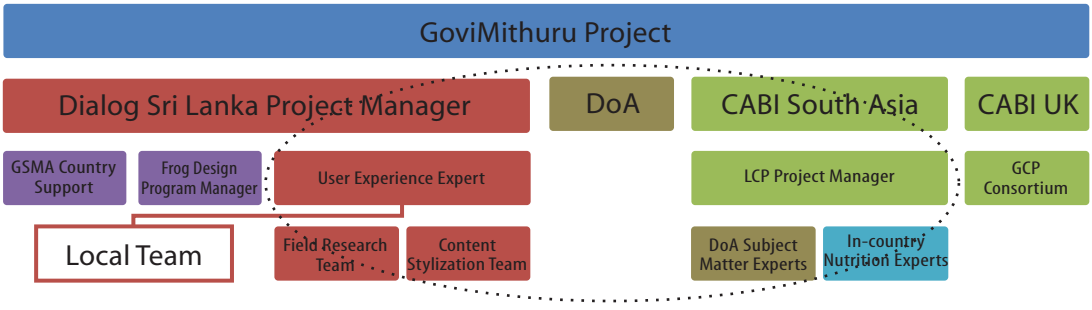


Figure B3: GoviMithuru Project setup

Capacity development/training

One of the key challenges in designing the GoviMithuru service was how to create engaging content for the farmers so that the researchers and other stakeholders are not only able to effectively communicate with the farmers, but also can create sufficient interest in their mind so that they remain engaged and continue listening to the messages. The key objective of communication development is that it should be participatory and help to induce long-term and sustainable behavioural changes. Hence, it was crucial for the content development team supported by CABI and its consortium partners to develop effective communication skills, especially in the writing of engaging short messages for dissemination through mobile phones.

Agriculture and nutrition are intricately interlinked with one another (Figure B4). Both food production and agricultural income affect household nutrition

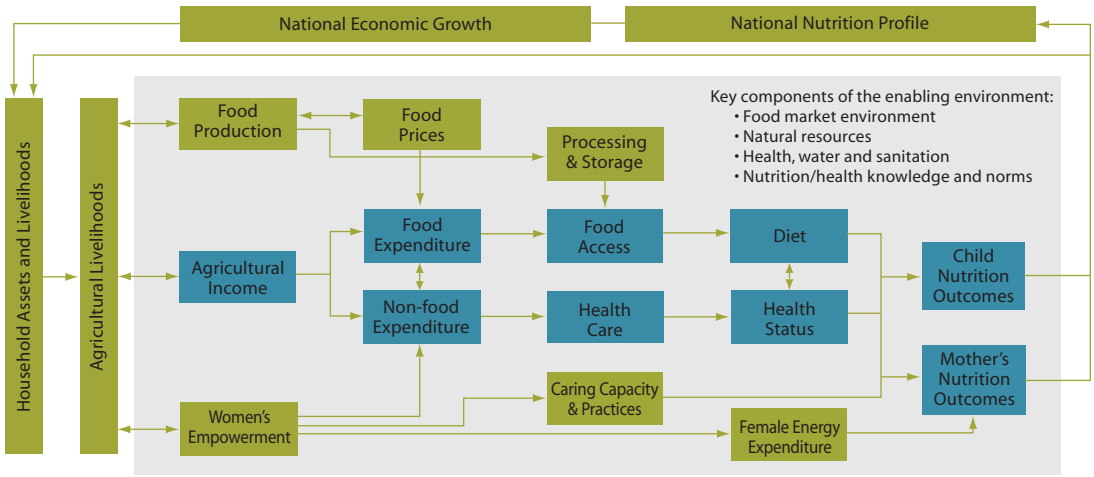


Figure B4: Agriculture nutrition pathway

Source: Herforth and Harris, Improving Nutrition through Agriculture Technical Brief, USAID, 2004.

and thus influence the national nutritional profile and overall economic growth and social factors such as women's empowerment.

Hence, while developing content, these complex interlinked relationships are to be kept in mind. The other key consideration factor is that because of mobile channels, messages have to be fairly short. Although GoviMithuru service messages are primarily voice messages, farmers still start to lose interest in listening to long messages. Through experience, it has been found that the optimal length of a voice message is 1-1.5 minutes. Within the message, there is a header, which contains a greeting to the listeners (farmers), introduction of the sender (e.g. Dialog Telecom) and the topic (e.g. brown plant hopper in paddy). Typically the header section is of 10-15 seconds length. After the header, the main content is communicated, which is typically 30 seconds to 1 minute in length. The message concludes with a footer section of 10 to 15 seconds, which reiterates key points in the messages (e.g. calling to a helpline number for more detail) or when the next message on this topic will be sent (e.g. "listen to our next advice on this topic next Tuesday"), a note of thanks and sometimes additional information such as the sponsor or validator of the message (in this case DoA Sri Lanka).

The key task of content development is to create content that should capture the attention of the listener in the first 15 seconds (Relevant), result in attentive listening behavioural change (Actionable), ensure that the intended information/ knowledge is passed on to the listener (Comprehensive) and motivate the listener to seek more information (Engaging), concluding in subscription (Figure B5).

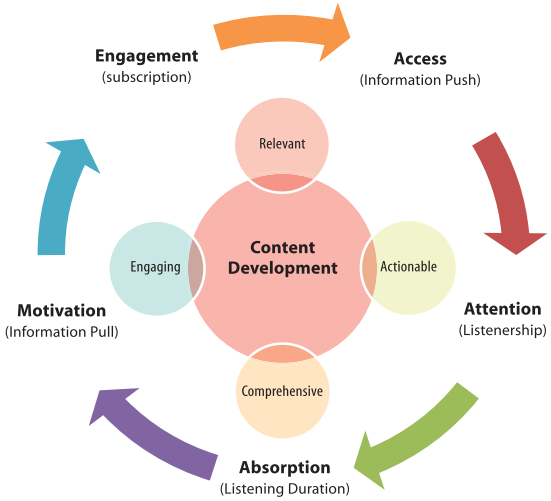


Figure B5: Content development methodology

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Figure B6: A content development write-shop in Sri Lanka with subject-matter experts from the DoA

In order to achieve this objective, CABI, along with the global consortium partners, organized communication development skills training events in Sri Lanka. Twenty officers from various functions and departments under the DoA were trained as trainers in the first phase. After the training events, cross-functional working groups were formed to work on content development. These groups were assembled at content write-shops in which the group was asked to intensively work on developing 'farmer friendly' messages on a chosen topic. During this process, officials were engaged without disturbing their regular duties and the quality of content was very good. As being cross-functional, the content was assessed from all angles.

Infrastructure

The GoviMithuru project comprises two kinds of infrastructure: the IT and telecommunication infrastructure, owned by Dialog Telecom, and the human resources from CABI, the DoA and Dialog.

CABI has a project office is Sri Lanka, headed by a project manager and supported by the Directorate of Information and Communication, DoA, Sri Lanka. The project office works with the different departments of the DoA as well as independent consultants for content development, validation and translation (Sinhala, Tamil and English)

Reporting

Project management follows Prince 2 project management principles. The day-to-day project management activities are managed by the project manager based in Sri Lanka, under the overall oversight of the Directorate of Information and Communication, DoA. The content manager and operation manager, based in the CABI office in India, support the project manager in managing the project. The global content consortium, led by

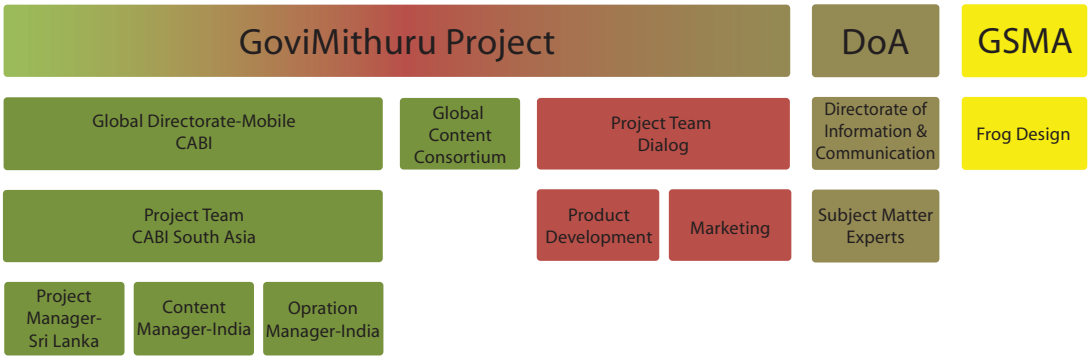

Figure B7: GoviMithuru Project Team Structure

CABI UK, support the local teams in India and Sri Lanka with regard to quality assurance and content development guidelines (Figure B7).

A similar project management team is in place at Dialog Sri Lanka, headed by a project manager, supported by a product manager. The Dialog team is assisted by the GSMA country support team and a design company called Frog Design for product development, user testing and so forth.

Both teams work in tandem with each other and quarterly reviews are organized by the DoA and chaired by the Director-General, DoA to monitor progress and support the teams through executive decisions.

Summary of system components/ requirements

The IT/telecommunication infrastructure of the GoviMithuru service comprises of the IVR system, which is available by dialing a short code (616) from the Dialog Sri Lanka network. In the backend, there is a telephony system that transfers the calls to either a computer server (for the automated voice messages) or to a customer care centre, where customers can register and/or make contact for any service-related issues. The customer care facility is also managed by Dialog.

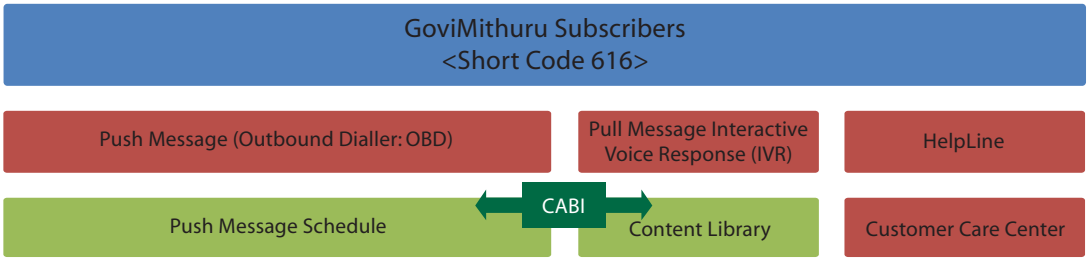

Figure B8: GoviMithuru Service Architechture

Innovations and key success factors

In designing and implementing the GoviMithuru project, the team has taken many innovative approaches that have given this service a unique advantage over other similar services available in Sri Lanka

- The first is the use of HCD principles for service design. Generally, the mAgri services evolve out of any exisiting rural products of the telecommunication companies (telcos). Thus, the competing services become more or less similar to one another and do not offer any significant value addition to the consumer, apart from different price points. However, by using the HCD process, the GoviMithuru product has developed bottom-up feedback and through the multiple iteration process, the service has been further refined. As a result, since its launch in October 2015, significant excitement and traction on ground has been observed;

- In order to reinforce mobile messages, various other promotional strategies have been adopted. For example, a wall calendar was developed, which, on each page, has an advisory on farming related to the respective time of the year and with specific information on how to use the GoviMithuru service to access relevant information on farming, along with general health and nutrition advisory information;
- To ensure that farmers get the right information at the right time, a messages scheduler was developed with the help of the Crop Calendar. For this purpose, the Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie (BBCH) agronomic scale was adopted into the crop calendar for local crops and agronomic practices. Accordingly a message scheduler was created, via which, personalized push messages can be sent to the farmers, based upon the sowing date provided by them during registration, proactively;
- Having the DoA, Sri Lanka as a partner in the GoviMithuru project has helped in achieving a high level of trust in the service by the farmers. Also, the content was designed in such as way that it synchronizes with key government policies and programmes and the farmers learn not only about good agriculture practices, but also understand government programmes and policies and benefit as a result;
- Regular user feedback through farmer contact activities has resulted in rapid service improvement. Dialog's product team regularly meets the user and also the non-user farmers in the areas where the service has been launched and does user testing in order to userstand the farmers' perspectives. These contact programmes are very popular and are attended by many farmers, especially women farmers, who otherwise are beyond most mAgri service coverage (mostly men own the handsets, so they subscribe to such services). The service feedback is analysed by the CABI team along with DoA counterparts and the subject matter experts are given the feedback, which helps them to fine tune their communication further. In this way, the project is also contributing to the national agriculture extension system of Sri Lanka, which benefits from such feedback while developing its communication strategy. Interestingly other private businesses, such as FM Channels have also started participating in such activities.

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Figure B9: Farmer contact activities in the GoviMithuru project are being attended by many women farmers

How it works: The GoviMithuru mAgri Service

The GoviMithuru service is a voice-based information push-and-pull service available to the subscribers of Dialog Telecom Sri Lanka. As of now, the service has been launched in the central provinces, however it can be accessed from anywhere in the island.

To use the service, farmers need to register (Figure B10). Currently the registration process is through a self-help IVR-based process, supported by a human agent (in case the users are not able to use the self-help menus). During registration, the profile of the subscriber is captured in a database, which is later queried to customize the content according to the profile. Special algorithms for this purpose have been developed.

After registration, the subscribers get three voice messages per week on agriculture and two voice messages per week on health and nutrition topics. The subscribers can also dial in the short code to listen to a library of content in the form of pre-recorded voice messages. The subscriber can also use the IVR to update the system from time to time with specific information such as crop sowing dates so that they get tailor-made information in line with their needs.

The system also generates large volumes of data on caller profile, location, listening duration etc. which are regularly analysed for gathering important information on user behaviour, usage patterns etc. as business intelligence.

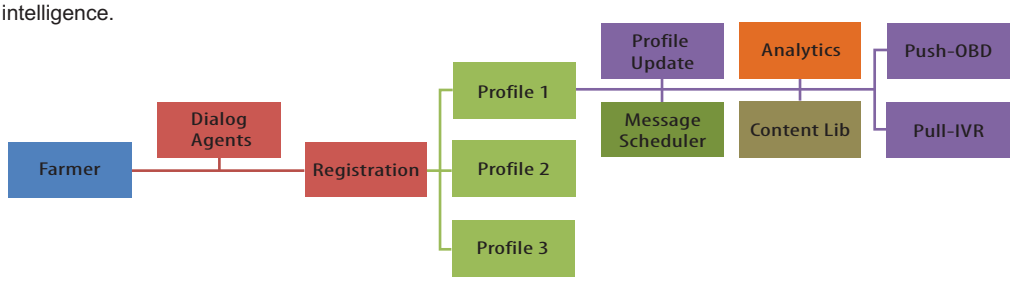

Figure B10: GoviMithuru mAgri services

Constraints

The key constraints in implementing the GoviMithuru project can be broadly classified under the following categories:

- Constraints related to marketing
  - Lack of understanding about smallholder perceptions and behaviours on mobile phone usage: Although 83 percent of the farmers has access to a mobile phone within the household, which makes mobile telephones the most potential means of communication to reach out to farmers, most of the people in rural areas still use mobile phones primarily for person-to-person communication and some entertainment such as ringtone download or listening to music. Hence, it is difficult to successfully make farmers change their current practice of seeking quick information from neighbours or agrochemical shops in times of trouble to systematic information seeking and learning thorugh mobile phones. In the project this constraint was addressed by organizing farmer contact programmes to demonstrate how to use the service and its benefits. Partnership with the DoA also helped to increase trust among farmers, which is important for behavioural change;
  - Low level of awareness among farmers on mobile phone-based services available for

farmers: Marketing in rural markets is very much different from marketing in urban markets. Most of the conventional advertising media are not very effective in rural situations. Hence Dialog uses its existing distrubution agent network for on-field promotional activities along with conventional digital media advertisement. The roadshows have been well accepted by the farmers and generate considerable word of mouth pubilicity; and

  - Low levels of willingness to pay for mobile phone-based agrarian services due to the existing government extension services which are provided free of charge: This is a universal problem with many mAgri services. The Government of Sri Lanka runs a service called 'Govi Sahana Sarana', which is a toll-free agricultural helpline. However through advertising and clear product differentiation, the GoviMithuru service has been able to establish itself as a premium service, although many farmers still do not like to pay beyond the trial phase. Hence, other complementary services, such as crop insurance, shall be introduced soon to give better value to the customers, motivating them to pay for subscription.

- Constraints related to content
  - Repurposing highly technical information into a simple, attractive message that can be comprehended by anybody is a big challenge. The subject-matter experts are not accustomed to writing in such style and intensive training is required to make them conversant with farmer-centric message writing;
  - The messages are also to be translated into vernacular languages without distorting the scientific facts. This is an even bigger challenge because most of the research information is only available in English and finding equivalent terms or expressions in local language is very difficult. However with support from the DoA, it has been made possible with the help of field extension personnel; and
  - Content scheduling has also been a problem as exact times of sowing of different crops are not known. Hence, it is difficult to foresee which life stage a particular crop would have reached at a particular time of year. However, as more and more farmers have started providing sowing dates, it is now becoming easier.
- Constraints related to policy environment
  - In Sri Lanka, 82 percent of land is owned absolutely by the state; there are no permanent user rights for tenants (farmers) to have adequate incentives for soil and soil nutrient conservation. Hence it is difficult to motivate farmers in adopting sustainable approaches such as conservation agriculture, natural resource management etc.; and
  - Services on mobile phones such as mobile money, mBanking etc. are still at a nascent stage. This poses difficulties in terms of introducing transactional functionalities in GoviMithuru, which is currently an informational service.

Lessons learned

The key lessons learned in the project (so far, since the project is still ongoing) are:

- HCD methods are very effective for product development. They help the business (and hence the designers) to connect more deeply with the target customers and help them to look at a wider perspective rather than focusing narrowly on the target market only;
- Having a robust user feedback mechanism is critical. In the project, because of timely and regular feedback from the farmers, the content development process was adapted to ground realities, resulting in larger audience and better engagement;
- Although there is a major need for agricultural information, willingness to pay for information

alone is low. This is because there is a general perception that agricultural extension is a public good, hence information should be open access. However, services providing information coupled with transaction (info-transactional) have a higher probability of monetization. The service designers should keep this in mind while designing mAgri services; and

- The government has a key role to play in mAgriculture, although this still remains significantly driven by the public sector. mAgri services should be complementary to the country's overall eGovernance goals and strategies. Only then there is a possiblity of long-term sustainability.

Sustainability

The GoviMithuru service evolved out of the TradeNet service (an online marketplace) of Dialog. Originally, during the inception phase, it was visualized that the TradeNet service would be augmented with agricultural information as value added (in fact the service was named GoviNet, for this reason). However, later on in the design phase, the service was completely reborn as a new mAgri service. In the current phase, the service is being run as a pilot to assess its long-term viability and sustainability. The early insights from piloting indicate that the service should be made more synchronous with the national eAgriculture strategic initiatives of Sri Lanka and should also integrate transactional functionalities in the service so as to create opportunities for monetization.

Actions have already been initiated in these areas. CABI has started looking at modalities of converging the service with its Plantwise programme in Sri Lanka, which, after successful piloting, has become a key extension initiative of the government (see http://www.plantwise.org/plant-clinics/plant-clinic-locations/sri-lanka/ for more details). Simultaneously, Dialog is also looking at the commodity sector as a potential area for info-transactional services such as crop advisory – insurance, for example. The CABI team is also helping Dialog in this area.

Replicability and up-scaling

The GoviMithuru service is based on simple yet robust IVR platform. The IVR system works on voice telephony; hence its reach is not limited by the availability of high-speed networks (2G/3G) or broadband data. All the functionalities of the service can be accessed by a simple mobile phone (no need for a smartphone), which makes it affordable to the poorer section of society. These features of the service make it easy to replicate in any country or market.

Nutrition-sensitive agriculture is fast emerging as the need of the hour. In many countries, excessive focus on increasing production of food grains has resulted in severe deterioration of health and nutrition conditions, as diet has progressively turned towards consumption of a single food grain crop. Many countries, which have achieved food security in recent times, are struggling with issues of low birth weight, stunting and other nutritional deficiencies, especially among children and women of reproductive age. The GoviMithuru service can emerge as a fine example of achieving better nutrition through agricultural interventions.

Hence, it is expected that after the pilot phase, the service will be scaled up nationally with new features and functionalities

Conclusion

Agriculture and nutrition are major priorities in Sri Lanka. Agriculture employs the second largest share of Sri Lanka's workforce, yet accounts for only about 11 percent of the country's GDP. More than 70 percent of rural women are involved in subsistence production and women have extensive workloads with dual responsibility for farm and household production (FAO 2005). Although smallholder farmers spend a major part of their income on food (Dissanayake et al. 2011), malnutrition is a major health and social problem among rural farming populations (FAO 2005). This signals the need to improve nutrition literacy among farming families.

Sri Lanka is performing well in ICT implementation. It ranks 116th in the International Telecommunications Union's (ITU) ICT Development Index 2016, higher than neighbouring countries such as India (138), Nepal (142), Pakistan (146), Bangladesh (145) and Bhutan (117). Sri Lanka also ranks high in adult literacy rates (92.63 percent) and gender equity (73: high human development), which makes the probability of success of any eAgriculture initiatives in Sri Lanka quite high. With this background, the GoviMithuru project is a good example of harnessing existing national resources and leveraging favourable conditions in developing mAgriculture services.

Through this project, a unique attempt is being made to influence nutritional conditions through intervention in agriculture, which in the long term will not only ensure food security, but also help in achieving nutrition security, thus resulting in improved overall quality of life. The GoviMithuru project is also a fine example of public-private partnership in development work. Throughout the world, it is increasingly being realized that without the equitable participation of private businesses, development efforts will not be sustainable. In this regard, this project can offer many important findings.

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For more information

Sharbendu Banerjee
Global Director-Mobile, CAB International, E-mail: s.banerjee@cabi.org

Electronic Solutions against Agricultural Pests (ESAAP)

Case study C

REAL-TIME INTEGRATION OF AGRICULTURAL INTERACTIONS REDEFINES EXTENSION

Objective

This study was part of a project sponsored by the Government of India to the University of Agricultural Sciences, Bengaluru to understand the impact of 'real-time extension' in crop health management at various levels — farmers, extension agents and subject matter experts. The objective was to empower extension agents with a tool that allows independent field diagnosis of crop health problems (insect pests, diseases, weeds and nutritional deficiencies), quantification of the problems and recommendation of specifically prescribed solutions. The same tool would, in turn, be used to capture various field data on the activities performed by the extension agents, like details of the farmers visited, details of the crops and the problems, images, audio recordings, spatial coordinates, etc., and to make these data available to policy-makers and other agricultural stakeholders in real time as ready-to-use reports. The project aimed to ensure real-time transfer of technology from the subject matter experts to the extension agents to facilitate application in the field. At the end of the project, an impact assessment of the same was conducted.

Geographical coverage

The project was implemented in two districts — Chikkaballapur and Ramanagar — of Karnataka State in peninsular India. The two districts are in the eastern dry zone of the state with annual rainfall of between 679 and 889 millimetres, elevation of 800 to 900 metres above mean sea level and mostly red loamy and lateritic soils. The total cultivable area in Chikkaballapur and Ramanagar districts is 286 100 and 175 539 hectares, respectively.

Introduction

Context

Strong and dynamically functional extension is essential for growth of the agriculture sector. The new mantra is to change from the present unidirectional (information flow to the farmer) to the future multidirectional (information flow through a network of stakeholders) perspective. The context here was to study a novel model of implementation to drive a multidirectional and real-time approach to agricultural extension using a powerful ICT system. Implementation thrust was on crop health management, which, after water availability, is perhaps the most worrisome issue for farmers during the cropping cycle.

Challenge

Crop health management encompasses problems caused by and remedies for diverse pestiferous species and nutritional deficiencies that decrease crop production and impact farmers' welfare. The disconnect with experts and other stakeholders, and lack of training inhibit extension agents from delivering the right solutions to the farmers. The challenge was to ensure that they become able to independently and accurately handle this diversity of problems and solutions. They should deliver irrespective of their personal skills and information. They should tackle every problem, new or old, big or small, with aplomb and enjoy a higher social status in the farming society. They should be the stakeholder nexus *vis-à-vis* crop health management.

Response

The solution was to digitally empower extension agents with a tool guiding them to accurately tackle diverse field situations and independently provide remedies that are in line with national regulations and recommendations. The tool shall ensure real-time transfer of technology in a manner that is appreciated and adopted by the extension agents. Further, the tool shall allow other stakeholders to interact with the extension agents in real time.

About the initiative

Electronic Solutions against Agricultural Pests (eSaAP), developed at the University of Agricultural Sciences (UAS) Raichur in association with Tene Agricultural Solutions Pvt. Ltd., Bengaluru is a tested ICT system dedicated for crop health management. Developed on an Android platform it is an offline solution that exchanges data with the cloud server under any telecommunication network. It has a unique (patent-published) image and voice-based diagnostic architecture, a mechanism to capture field data and is updated remotely. Realizing the gross disconnect between knowledge centres and extension agents, UAS Bengaluru and Karnataka State Department of Horticulture (DoH) submitted a proposal to the Department of Administrative Reforms and Public Grievances, Government of India, to utilize eSaAP for developing a real-time network between the two institutions so that farmers could be provided with accurate and timely solutions to their crop health issues. The project was implemented from November 2013 to May 2015 in Chikkaballapur and Ramanagar districts. In addition to the extension staff of the Horticulture Department, who were expected to use eSaAP whenever needed, field officers were specifically recruited under the project to perform the defined activities every day. Also, the Krishi Vigyan Kendras (KVK), or the extension centres under UAS Bengaluru, in each district were actively involved in assisting the extension agents. Impact on farmers, extension agents and subject-matter experts was studied towards the end of the project period.

Outcome

During the project period, 16 813 field pest problems were diagnosed and suitable pest management measures were advised by the extension agents. Of these, 92 percent were resolved by the extension agents in the field without external support. The remaining 8 percent of the problems were resolved through eSaAP's expert management system in near real time. Nearly 90 percent of the farmers were satisfied with the solutions provided. Rural youth Field Assistants (FAs) efficiently diagnosed the problems in farmers' fields using the eSaAP system. They established good rapport with the farmers and were repeatedly invited for consultation, which suggests that there is great scope for self-employment among rural youth as digitally-connected extension agents.

Stakeholders and partners

UAS Bengaluru was the primary implementer of the project. It was responsible for the agricultural content dealing with diagnostics, survey plans and management strategies; coordinating with other stakeholders; recruiting and training of extension agents; monitoring field activities and suggesting corrective actions; popularizing the services created under the project among farmers; reporting field situations to administrators for need-based actions; evaluating the impact of the project on farmers, extension agents and subject matter experts; and for reporting to the funding agency. Scientists at the KVKs partnered in the project. They resolved some of the difficult problems faced by the extension agents in the field through the eSaAP expert system. When need arose, the KVK staff visited the fields too. The state DoH was the primary stakeholder as the

project aimed at empowering its extension agents with eSaAP who were thus thoroughly trained in using the eSaAP field devices. The district-level officers and other decision-makers were trained in using the eSaAP system for obtaining real-time reports on the field situations. The local rural youth of the two districts who were recruited under the project formed an important stakeholder group. They were diploma holders in agriculture with practical experience in farming who were trained and involved full-time for extension activities envisaged under the project. Their performance was one of the key success criteria of the project. In line with the project's vision, farmers formed the target beneficiary group to minimize preventable crop losses caused by pests as well as poor nutrition.

Methodological approach

Requirements

eSaAP is a platform that needs to be customized for each client, especially with respect to content related to crop health management, including images, translation to local language and audio recording. The contents include pest diagnostics, survey and sampling methodologies to quantify the intensity of damage, defining economic threshold levels for each pest species at a particular stage of a crop and damage-based management strategies. Under this project, the required content was developed and incorporated into the eSaAP platform for 14 important horticultural crops of the two districts that are prone to pest problems — mango, banana, papaya, grapes, tomato, brinjal, okra, hot pepper, beans, cabbage, ridge gourd, rose, jasmine and coconut. A separate cloud instance was set up for the purpose. The physical requirements included field devices such as 7" tablets with suitable specifications, portable bluetooth-enabled thermal printers for printing the prescriptions and handing them to the farmers, and SIM cards from any of the telecommunication service providers operating in the target area that can exchange data with the server.

Personnel and capacity development

An implementation plan was put in place after several rounds of discussions with officers of the DoH. At the outset all district officials of Ramanagar and Chikkaballapur, up to the last mile, were prepped for the same. Once the field devices were ready with the content, all the officials were trained hands-on with respect to using the device and the eSaAP system. There were 20 extension personnel in Chikkaballapur District and 14 in Ramanagar District from the DoH. In addition ten local rural youth FAs, with diplomas in agriculture, were recruited and trained in pest management and in using the devices. Five FAs were placed in each district and each had a specific area of operation. Officials of the KVKs were also trained in handling both the field devices and the Web application of eSaAP; the Web app allows them to monitor all the field activities with real-time data flowing in and presented as maps and graphs. Similarly, the higher officers of the DoH and those from UAS Bengaluru were trained in using the web app as they could access real-time data on the field situations for taking up need-based actions. Importantly, an expert team was put in place comprising entomologists, pathologists, physiologists, horticulturists, soil scientists and extension specialists to support extension agents and FAs. The expert team was not only in charge of the content published in the field devices, but was also responsible for assisting the extension agents and FAs whenever they were confronted with a difficult-to-diagnose situation; the eSaAP expert system allowed the experts to respond from

any place in real time. An important follow-up action needed for the success of the project is regular monitoring of field activities, identifying persons needing retraining and providing the same.

Infrastructure

The infrastructure required included laboratory space for a few people handling the content and monitoring field data; the laboratory was equipped with computers, high speed Internet connection, backup power and so forth; there was also a training room with necessary furniture, Internet connection, projection system, etc.

Reporting

Reports on the pest status of horticultural crops, especially highlighting the ones that were important, were prepared and sent to the DoH at 15-day intervals. The reports included space-time data on pest activity and the management strategies so that the officials could take suitable action. Otherwise, reports on the overall status of the project were submitted to the funding agency at defined time intervals.

Summary of the system components

The key components of the project included the eSaAP system, the expert team, the extension agents and the managers/administrators. In terms of actions, capacity development of the extension persons, including local rural youth, and that of the policy-makers and other stakeholders; monitoring activities of the extension persons/FAs and retraining; and real-time action by policy-makers, researchers and other stakeholders were important for the success of this and similar projects.

Validation

eSaAP had been validated by UAS Raichur and several other institutions and expert teams over a few cropping seasons prior to its adoption in the current project. Feedback was siphoned by the DoH, and a plan is now underway for a state-wide implementation. Additionally, the Karnataka State Department of Agriculture has already initiated steps for deployment of eSaAP as a state programme. The Government of India too has initiated steps towards nationwide deployment of eSaAP in the same model as conducted in the project explained here.

Impact

In the nine months of field deployment 16 813 pest situations were addressed. Of these, 15 424 situations were addressed independently by the extension agents and FAs, which is a remarkable achievement. More so as they could achieve an accuracy of 90 percent while diagnosing field issues. During this short span, two new pests were discovered for the first time in the areas of operation — tomato pinworm and banana skipper. It only took a few minutes for the experts to upload the identification process and the remedial measures in the eSaAP system, which was updated in real time in all the field devices. The inbuilt architecture in the devices allows the field persons to diagnose new problems and provide solutions to the farmers without any training. Periodic alerts were sent to the authorities regarding many pest situations of considerable importance (late blight of tomato, hoppers and powdery mildew in mango, etc.), prompting them to take area-wide actions. The fact that farmers called the FAs repeatedly to investigate health issues of various other crops was perhaps the most satisfactory impact of the project.

Innovation and key success factors

This project was the first to bring about a real-time digital marriage between the UAS Bangalore (expert team) and the DoH (extension team) to resolve a major issue that affects agriculture, i.e. crop health management. The resounding success of this innovative implementation clearly suggests that this would be a reasonable way to go forward. Some of the key success factors have been that ~88 percent of the farmers indicated that they were able to manage the pest situation successfully. In fact, about 65 percent of the farmers thought that there had been an increase in yield by up to 25 percent.

Constraints

The extension agents from the DoH are often involved in many other activities, which frequently do not provide them with sufficient time for field visits. As a result, most of the 16 813 field visits were made by the FAs. This was perhaps the single most important constraint.

Lessons learned

The important lesson learned was that local rural youth can play an important role as extension agents. When trained and networked in real time with experts and other stakeholders, they can independently handle field problems with ~90 percent accuracy. They can fill the great void in India with respect to agricultural extension coverage and serve to integrate the entire sector. With rapid digital penetration into rural India, and with technologies such as eSaAP that drives core agricultural processes, real-time multidirectional flow of data can become a reality. Every other stakeholder, not just the farmer alone, shall benefit from a transparent flow of data in real time that is required for decisions of national importance.

Sustainability

Sustainability depends on a sound revenue model for the trained local rural youth, a vibrant expert team that interacts and continuous evolution of the ICT tools involved.

Replicability and scalability

The system is easily replicable anywhere in the world. Some of the things that facilitate replication include the flexibility in eSaAP to suit local content and language in any part of the world. The model proposed here is easy to replicate. Further, technicalities can be managed from any part of the world. For example, if a nation is not equipped to handle the technical aspects of crop health management, the same can be managed remotely by international organizations from anywhere, or by another technically advanced nation.

Conclusion

It is clear that the right ICT tools and functional implementation models can bring about true integration of the agriculture sector, which is necessary for its growth. Elements like prescription-based agriculture, remote management, real-time data for decision-making and developing prediction models, rural empowerment and employment can be made a reality.

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For more information

K. Murali Mohan
Assistant Professor of Entomology, College of Agriculture,
GKVK Campus University of Agricultural Sciences, Bangalore, INDIA
E-mail: entomurali@gmail.com

A. Prabhuraj
Professor of Entomology, College of Agriculture,University of Agricultural Sciences,
Raichur, INDIA
E-mail: prabhusha2014@gmail.com

Y.B. Srinivasa
Managing Director, Tene Agricultural Solutions Pvt. Ltd.,
E-mail: yb@tene-ag.com

Opssmart® Traceability Solutions

Case study D

Objective

Food-borne illnesses pose a serious health threat to the world population. In the United States alone, according to United States Department of Agriculture (USDA) estimates, the economic impact of food-borne illness is over US$15.6 billion annually. The USDA's estimates include costs associated with productivity loss, medical costs and even death. They do not include the huge costs levied upon the food industry.

To date, no singular panacea can be found that can help prevent or minimize this impact. There is a need to implement frameworks that are efficient, concise, detailed, swift and that can span the length and breadth of a supply chain such that specific key information regarding any product, by-product, raw material process or business component can be instantly accessible across all touchpoints of the supply chain. The benefits of such a framework, beyond offering supply chain management, will be to swiftly compile and present highly critical and needed information regarding any raw material, product, by-product or process, laterally or vertically across the entire supply chain. This allows problems to be detected early to avoid its proliferation, which may cause illnesses. If there is a problem, withdrawals and recalls can be swiftly and narrowly focused.

OpsSmart's farm-to-fork traceability solution offers such a framework as a by-product of its traceability features. It brings transparency to the food supply chain by tracking raw materials, including tracking of each critical control point (CCP) from origin through to finished products. OpsSmart leverages the inherent power of captured and collected supply chain information to deliver early detection of problems, issues or concerns in avoiding food-borne illnesses. In the event of a problem at any point in the supply chain, OpsSmart is able to facilitate quick and accurate trace-back to the source of the problem and provide lateral traceability of other food lines that may have been affected by the same problem source.

Geographical coverage

The global food trade has made the need for traceability a worldwide issue. While increasing globalization of the food supply chain makes ensuring the safety of food more complex, it also makes it more difficult to ensure the ingredients in finished ready-made meals and processed foods are safe for human consumption. Although the need for traceability in the food supply chain is a global issue the following case study will focus on Thailand's national response towards this global issue.

Introduction

The food industry is facing a crisis of confidence over the issue of food safety, purity and provenance. While contamination of food products is the major concern, there are other related issues of food provenance, such as Genetically Modified Organism (GMO)-free, antibiotic-free, organic and non-organic, kosher and halal food products. The current climate of concern over terrorism adds yet another concern with the possibility of food bioterrorism.

Food-borne illnesses contribute to a significant portion of the health care cost to society. According to the World Health Organization, worldwide, an estimated 600 million people – almost 10 percent of the world population fall ill

as a result of consuming contaminated food and 420 000 die each year as a result.

Consequently, global governments as well as consumers are increasingly demanding traceable and safe food for consumption. To protect their own interests, commercial stakeholders want to quickly and affordably satisfy these demands as well. Governments around the world are also increasing and enforcing food safety standards, which is mounting the burden on industry to comply with the new food safety requirements.

Yet, the problem is not only one of implementing new processes within the supply chain, such as Hazard Analysis Critical Control Points (HACCP), ISO or best practices such as Good Agricultural Practice (GAP), Good Manufacturing Practice (GMP) or Good Distribution Practice (GDP). Because a problem at any CCP throughout the entire supply chain can lead to food-borne illness and may even cause fatalities, it is crucial to capture the critical information from these processes within a singular traceability information flow, with the goals of providing safer food, simplifying product recall, removing duplication of data and being able to identify the risk areas within the supply chain.

One of the major problems facing the industry is the inaccessibility of critical information embedded within the supply chain largely due to ineffective methods for tracing the entire life cycle of a product from origin to finished product. Traditional paper-based records have proven extremely slow and inaccurate and lack seamless information flow throughout the supply chain (Figure D1). To ensure the safety of the food supply chain, each supply chain partner must have an effective 'internal traceability' system. In addition, the supply chain partners must also be able to share food safety and quality information with their trade partners.

Figure D1: Chicken supply chain

This study will show how the OpsSmart solution is utilized by a large agribusiness that traces raw materials from origin though the production process and through distribution to the grocery store. It traces each CCP from raw material to finished product. The study will next examine how OpsSmart is used by a large food retailer to ensure the products it purchases from its suppliers is safe to eat and meets its quality standards. With agribusinesses and retailers acting as partners sharing information, the industry can ensure the food we eat is safe.

The OpsSmart solution – safety, management and compliance through traceability

OpsSmart Technologies, Inc. is a software development company that delivers innovative full-chain food traceability and quality assurance solutions.

OpsSmart traces the origin of raw materials from the source, through the manufacturing processes, all the way through retail outlets and to the end consumers while facilitating tracking of CCP thresholds within an enterprise, and throughout the entire supply chain (Figure D2). OpsSmart further strengthens the internal and external auditability of the supply chain records through efficient document management capacity.

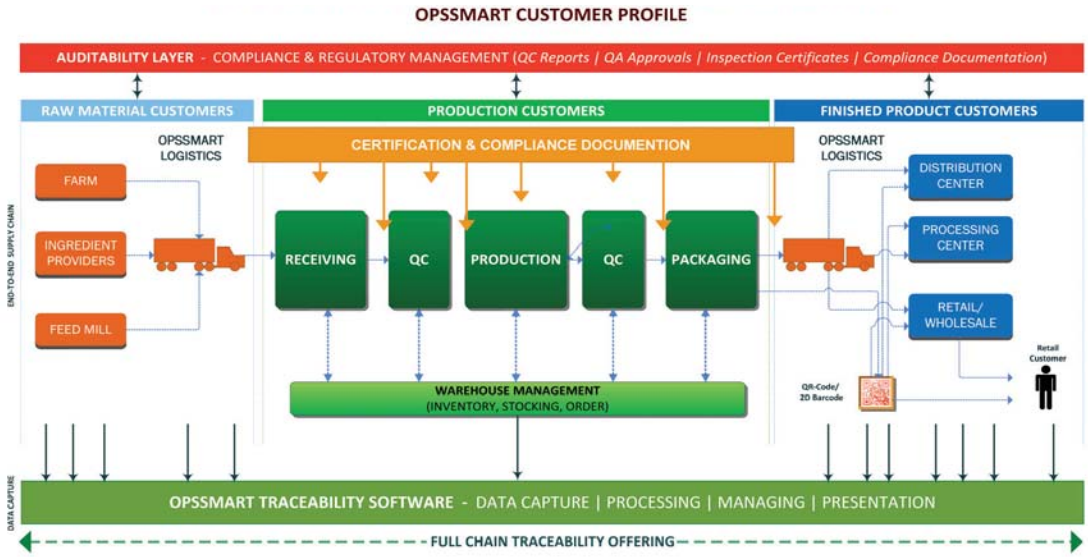


Figure D2: OpsSmart full chain traceability solution

OpsSmart is used for internal traceability by all types of stakeholders in the supply chain from feed mills, farms, slaughterhouses, further processing facilities, retailers as well as governments. Each supply chain partner owns and controls their own data and they can share their data based on agreements among the partners.

This case study shows how some of OpsSmart's customers in agribusiness and retail industries utilize OpsSmart traceability solutions to provide farm-to-fork traceability to ensure the safety of the food supply consumed in Thailand and exported from Thailand is safe to eat.

Agribusiness

The Betagro group

The OpsSmart Cloud-enabled Traceability Solution allows Betagro to accurately trace food safety, quality and origin information across the entire supply chain. OpsSmart traces Betagro's poultry and swine operations from parent stock to finished products and all the way to the grocery store helping Betagro secure market access, increase consumer confidence, increase brand loyalty, improve operational efficiency, enhance products/ processes and reduce information technology capital expenditure.

Betagro is recognized as a major player in Thailand's agro-industry and food business, engaged in animal feed production, livestock and animal health products, and most importantly, high-quality, safe food products. Distributed to local and overseas markets, these leading, branded products respond to the diverse needs of consumers across the globe, reflecting Betagro's guiding principle: *Let's Make Life Better.*

Betagro produces high-quality food products such as fresh chicken meat, frozen cooked chicken products, fresh pork meat, soup bases, sausages, eggs and processed and frozen foods to serve both domestic and international markets. Betagro's operations include nearly 6 000 facilities including hatcheries, feed mills, parent stock farms, farms (both company owned and contract farms), slaughterhouses, veterinary pharmaceutical and health products, manufacturing facilities and further processing facilities.

The challenge

Traceability laws and regulations continue to evolve and mature in many large food importing markets including the European Union, Japan and the United States. As a result of its diverse food business footprint, Betagro deployed traceability systems in each of its food-related operations. However, these diverse systems could not be unified due to interoperability issues stemming from different formats and software application platforms and environments including paper-based systems. To accommodate its continued expansion in various food markets and product categories as well as to support the complexity of its business, Betagro needed a solution that would enable it to quickly access trace information throughout its integrated business ecosystem while ensuring that each step of the production process would be of the highest quality and satisfy domestic as well as international stakeholders. In addition, Betagro wanted a solution to improve its business information exchange needs with existing systems as well as offer flexible alternatives to existing paper-based environments while meeting the unfulfilled traceability requirements.

The solution

Betagro selected OpsSmart as its enterprise traceability and food quality assurance trace solution to manage its traceability needs across its entire operations.

OpsSmart's professional services team collaborated with Betagro for planning and implementation of OpsSmart to ensure that the enterprise food safety and quality assurance goals were thoroughly and consistently met throughout

Betagro's food operation. OpsSmart implemented the Software as a Service (SaaS) solution to allow for swift and seamless access to traceability applications regardless of the geographical location of Betagro's various business units.

The initial deployment of the OpsSmart solution was accomplished at Betagro's poultry operations. This deployment was divided into seven key implementation projects coinciding with operation types such as parent stock farms, hatcheries, feed mills, pharmaceuticals' manufacturing, broiler farms, slaughterhouses and further processing facilities. OpsSmart provided each operational business unit the flexibility to define machine number, farm location and production time at any point in the operations either forward or backward with easy configuration and versatility in matching an enterprise's business model. OpsSmart has fulfilled the diverse traceability needs of Betagro's various business units and their existing information systems. The Electronic Data Exchange (EDE) module within OpsSmart has streamlined the data exchange with Betagro's legacy systems while its traceability engine has been implemented without any system-level modifications or re-implementation of the legacy enterprise resource planning (ERP) systems. OpsSmart's configuration tools further offer the flexibility to allow for changes in the enterprise traceability systems to be instituted rapidly in order to meet the ever-changing environment within the food industry.

OpsSmart provides Betagro's management, authorized personnel and trade partners with the ability to quickly view the trace information within each operation and throughout the entire integrated supply chain. OpsSmart's traceability module, TraceItSmart®, swiftly enables Betagro to explore data in a multidimensional manner and perform traces filtered by item identification or other item-related attributes such as machine number, farm location and the production time at any point in the operations either forward or backward.

The benefits

Secure market access

OpsSmart tracks Betagro's compliance to government regulatory and customer protocols. Betagro is able to meet traceability requirements based upon a one-up one-down principle and beyond. Ready-made meals can be traced back not only to where the chickens/swine were slaughtered, but also to which farms they were raised. The ability to keep up with these increasingly strict regulations and customer demands helps to secure Betagro's market access.

Increased customer confidence

The implementation of the OpsSmart online traceability system demonstrates Betagro's commitment and ability to produce and deliver safe, quality foods. It reveals transparency of processes and enables Betagro to rapidly respond to local authorities and customers. Consider Better Pharma as an example. A purchaser of a Betagro pharmaceutical customer called at 18.00 to report a problem with a lot produced in the prior year. Quality assurance personnel were able to trace all lot-related information within a few minutes and to provide appropriate feedback. Without OpsSmart's online traceability system, the customer would have had to wait for a response until the next morning after employees searched through thousands of documents. This well-managed traceability information system builds customer confidence in Betagro's control over quality and the safety of produced lots. The customer can also gain automatic access to traceability information depending on the business relationship.

Increased brand loyalty

By placing quick response (QR) codes on the finished products Betagro brings transparency into

the supply chain and provides confidence to consumers that the products they are purchasing are of the highest quality and are safe to eat. Using the QR code reader on smart devices, consumers can quickly trace the origin of the products they are about to purchase all the way to the farm. This transparency and accountability built into the supply chain enables Betagro to elevate consumer confidence in its products, increases brand loyalty and enables Betagro to charge a premium for their brands.

Improved operational efficiency

OpsSmart enhances Betagro's operational efficiency by provisioning supply chain, operation and process information at its fingertips. Betagro is now able to make important business decisions regarding labour, processes and equipment based on near real-time information about its entire supply chain ecosystem.

Product/process enhancement

All steps of the production process are interrelated and have a cumulative impact on the quality and safety of final products. Traceability across the entire supply chain provides invaluable information for end-product quality improvement. OpsSmart drastically reduces safety and quality control challenges by enabling the user to trace across a multitude of data facets and product- or process-related attributes including item identification, production time, line numbers etc.

Reduced IT capital expenditure

The SaaS model relieves Betagro from the costs of hardware purchases, upgrades and ongoing management of the software system and application environment. At the same time, it provisions consistent and standardized synchronous application availability to all enterprise users, regardless of geographic location, operating platform or business role. OpsSmart manages the dissemination of suitable and role-appropriate information when and where it is needed while allowing the users to concentrate on the mission of the business.

Audit readiness

Being in the food industry Betagro needs to be prepared at all times for internal audits, second-party audits as well as government audits. With OpsSmart traceability solution, data on CCPs, all records and documents are stored electronically. Each and every record and data management element has an unalterable date and time stamp assuring data integrity for audit compliance. OpsSmart has improved Betagro's audits from a labour-intensive time-straining process into a fast, effective and accurate on-demand process. All of the data and records across the entire supply chain are accessible at the click of a mouse.

Reduced labour cost

In Betagro's earlier system, documents were filed by day for each production and quality assurance unit. To compile a complete picture, it took many staff a significant amount of time to search for the related production and quality records for recently produced batches. Researching older or archived production records was considered a monumental task. Implementation of OpsSmart has significantly shrunk the information research cycle from hours and days to within seconds. Betagro staff can now accurately access required information immediately thereby eliminating the need for manual review of individual hard copies thus increasing productivity and saving significant staff time.

Retail: Tesco Lotus

OpsSmart's Cloud-enabled Traceability Solution allows Betagro to accurately trace food safety, quality and origin information across the entire supply chain. OpsSmart's uniform portal solution allows Tesco Lotus food suppliers to efficiently upload safety and quality information regarding supplied food products as required by Tesco Lotus.

Tesco Lotus began its operations in Thailand in early 1994 as a food retailer and is currently the second largest international business of the Tesco Group. Serving over 12 million customers weekly in over 1 700 stores across Thailand, Tesco Lotus employs 50 000 full-time staff.

The challenge

In order to achieve uniformity within its quality control processes, Tesco Lotus wanted to develop a singular system ensuring that all of its suppliers meet its minimum safety and quality standards across its supply chain.

Tesco Lotus envisioned a system that could enable it to further improve consumer confidence in the Tesco Lotus brand as well as the products it sells, thus providing Tesco Lotus with a competitive differentiator and an additional communication channel with its customers.

At the same time, Tesco Lotus wanted to use this system to accurately obtain quality, safety and provenance information from its supplier within the supply chain.

Furthermore, Tesco Lotus wanted to enhance consumers' buying experience by offering them safety and quality information about the products while they are in the grocery store. Last but not least, Tesco Lotus needed to alleviate the burdensome work flows associated with audits by instituting efficient and rapid audit methodology and processes, preferably as a by-product of a centralized information ecosystem.

The solution

Tesco Lotus worked with OpsSmart to architect and deploy a cloud-based traceability portal for collecting, managing and disseminating product safety, quality and provenance data from the supplier within its supply chain.

OpsSmart's professional services team collaborated in planning, architecting and implementing a cloud-based traceability portal that now enables Tesco Lotus suppliers to directly and efficiently upload food product safety, quality and provenance information required by the company's supply chain mandates.

Currently, the OpsSmart traceability portal supports fresh produce packing houses and farms, meat and poultry processing facilities, and egg production facilities supplying Tesco Lotus in Thailand.

With OpsSmart's guidance, Tesco Lotus developed custom product traceability templates deployed in the traceability portal to accurately collect, compile, manage and disseminate product and producer information based on the risks associated with each type of product and producers within the company's supply chain.

The centralized portal mechanism enables Tesco Lotus to enforce upload and collection of suppliers' information in a uniform and standardized format while enabling suppliers to either upload data online or use the electronic data exchange facility whenever and wherever needed.

The benefits

Increased brand loyalty: By placing QR codes on the finished products, Tesco Lotus brings transparency into the supply chain and provides

confidence to the end customers that the food products being sold within its outlets are of the highest quality and are safe to consume. Using the QR code reader on smart devices, consumers can quickly trace the origin of the products they are about to purchase all the way to the farm. The ability to trace all ingredients in food products including ready-made meals and the transparency and accountability built into the supply chain, enables Tesco Lotus to elevate consumer confidence in its products, increases brand loyalty and enables Tesco Lotus to garner premiums for its brands.

Quality control: This allows Tesco Lotus to manage its product stock. Food products arriving at the distribution centres can be swiftly and efficiently verified and routed to the correct store reducing inventory lags. The traceability portal additionally allows Tesco Lotus to track merchandise receipts and archive important compliance information including cleaning records, shipment portfolios, packaging information, inspection records and certificates, production processes and packaging information.

Cost savings: The OpsSmart traceability portal facilitates the audit process by reducing audit-associated work flow and resources, and minimizes the amount of time that the auditors need to spend on the suppliers' site.

It further simplifies and reduces the time that inspectors need to conduct on-site inspections of Tesco Lotus suppliers.

The simplification of the audit process also minimizes and in some instances eliminates paper work thus increasing accuracy and information integrity. Furthermore, internal and external audits can be conducted with similar efficiency and finesse due to the centralization of the information.

Benefits to Tesco Lotus suppliers

Availability and access to markets: Furnishing food product safety, quality and provenance information according to the company's established requirements enables suppliers to gain access to one of Thailand's largest food retailers and results in exposure of their food products to millions of satisfied and repeat consumers.

Achieving consumer confidence: Through the implementation of QR codes as required by the company, suppliers earn consumer confidence by providing product safety, quality and provenance information on their specific food products. Additionally, consumers can easily review proper government certifications by simply scanning the QR codes, thus further increasing their satisfaction and trust in the products' viability, integrity and reputation.

Ability to track product batches or lots: Suppliers can easily track and trace their production output down to batch and lot with high precision enabling them to furnish production data to Tesco Lotus when required without spending any additional resources or time. This further enables the suppliers to trace even the ingredients within their prepared foods thus strengthening consumer confidence and enhancing the value of their specific products.

Inventory tracking and control: Inventory tracking increases suppliers' efficiency and order fulfillment through accurate and precise information sharing with Tesco Lotus as well as control of their own raw materials, logistics and schedules.

Conclusion

Each stakeholder in the food supply chain has a vital role in ensuring the food people eat is safe. A problem at any CCP in the supply chain starting with the producer of the raw material to each partner in the supply chain that handles the material until it reaches the consumer, ultimately can result in fatal consequences.

Full chain traceability allows each participant in the supply chain to track the origin of the materials from receipt and all of the CCPs within their

operations. By having trade partners share traceability information, in the event of a problem, its source can be rapidly detected and any other products affected can be recalled. In the event of a recall, having all of the traceability information also provides the ability to accurately pinpoint the source and size of the recall so it can be efficiently and swiftly mitigated.

For more information

OpsSmart Technologies Inc.
E-mail: info@opssmartglobal.com

TraceVerified

Case study E

ELECTRONIC TRACEABILITY SOLUTION FOR AGRICULTURE

Objective

TraceVerified is the very first transparent information and electronic traceability service in Viet Nam. Using barcodes and QR codes to store historical information makes access to commodities extremely easy via any smart device.

The objective of this project is to help Vietnamese consumers gain better access to transparent information and the provenance of foods on the market.

Food producers input all information relevant to the history of products into the database of TraceVerified. After the information has been confirmed as accurate, the products are labelled with traceability stamps (barcodes and QR codes or significant signs). Consumers can scan the code or read the stamps to obtain transparent information on the provenance of products.

TraceVerified helps farmers and food producers to build credibility and competitiveness in the market. Moreover, consumers can purchase domestic foods with clear provenance that has not incurred extra cost.

Geographical coverage

TraceVerified delivers services in all provinces in Viet Nam. In the first phase of the project, it focused on fishery and aquatic products. The service is delivered to provinces in the Mekong Delta such as Can Tho, An Giang, Hau Giang and Ca Ma. TraceVerified now serves vegetable farms in Lam Dong Province, the largest tropical vegetable cultivation area in Viet Nam, and the rural area of Ho Chi Minh City and Hanoi. Additionally, TraceVerified is working on the dragon fruit supply chain with cooperatives in Binh Thuan Province in the southern central region. TraceVerified is also spreading to the north central region, especially Ha Tinh, for traceability in the pork chain.

Introduction

Context

Agriculture and food production provides livelihoods for more than 10 million Vietnamese farming households. In 2015, agricultural exports from Viet Nam reached US$30.14 billion; Viet Nam's domestic food market was US$29.5 billion for a population of 90 million.

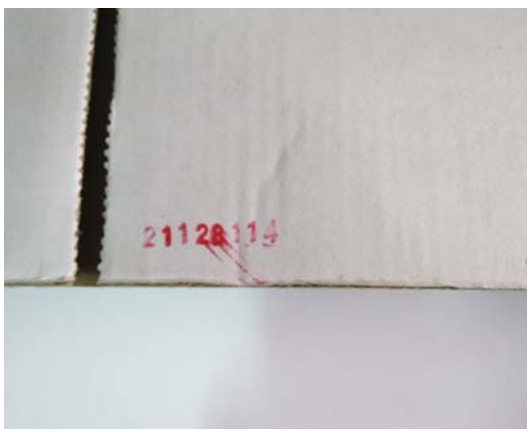
There are many regulations as well as quality standards that required traceability of food products. For example, the European Commission's regulation 178/2002/EC requires the establishment of a trace verification system at each production stage. Product information must be recorded and goods have to be labelled correctly to provide data on point of origin tracing. The Anti-Bioterrorism Legislation issued by the United States in 2004, states that exporters must send an origin tracing report to the corresponding authority four hours before shipments reach the port. Viet Nam has the Food Safety Modernization Act (FSMA), Circular 03/2011/TT-BNNPTNT (providing guidelines for tracing the origin of seafood products and revoking substandard seafood products) and Circular 74/2011/TT-BNNPTNT (providing guidelines for tracing the origin of foods and farm produce and dealing with

substandard foods and farm produce). However, unsafe food scandals appear with high frequency, leading to consumer distrust about food safety.

Although food producers make efforts to build an internal traceability system with much paper work, they are confronted by many constraints:

- Many paper records that results in bulky storage;
- Time-consuming work in locating records; and
- Information management risks (data loss, data integrity issues).

The photo below (Figure E1) illustrates the status quo, showing the trace code on a carton containing catfish products for export. It was taken at the warehouse of a seafood exporter in Can Tho.



© TraceVerified

Figure E1: Trace code on a carton containing catfish products for export

When buyers make tracing inquiries, they scan the codes on these carton boxes and contact the Vietnamese producers who search their document files and relay information back to the inquirer. This process can only meet buyer's tracing requirements at a minimal level, which is time consuming and often unreliable.

While Vietnamese consumers get a little information about the food they purchase; the amount of trusted, verified information on food products is even less. For most small- and medium-scale food producers, even if they follow good production practices, it is difficult to convince the broader consumer audience to believe in them because of old-fashioned communication channels and lack of verifiable, third-party validated product information.

Challenges

The main risks to TraceVerified's success are that food producers and distributors do not yet see the value-adding potentials of implementing traceability systems. They hold the perception that traceability systems are costly and time consuming. The Vietnamese Ministry of Agriculture and Rural Development requires food producers to keep paper-based tracing documents, however policy or incentives to encourage the adoption of electronic traceability systems are yet to be developed.

Most producers are not transparent about their commodities. This is a chronic problem among Vietnamese businesses which eschew sharing of information. Verification of information given by the manufacturer is also an issue. TraceVerified needs to ensure that public information is accurate. Moreover, farmers in general are reluctant to adopt new methods or to change their routine tasks.

Consumers in Viet Nam, even urban middle-class consumers, are not aware that they can use a simple scanning app on their smart phones to find essential information on the origin and quality of food products they buy from shops and supermarkets.

Initiative

Believing firmly in the necessity and potential for electronic traceability solutions for the Vietnamese food industry, in 2011 the Sac Ky Hai Dang Company made a proposal to the Global Competitiveness Facility (GCF) funded by the Danish Government (via Danida) to start the

TraceVerified project, which included electronic traceability, training and consultancy services for fisheries and other agriproduct value chains for small and medium enterprise (SME) exporters in eight target provinces. As a trademark, 'TraceVerified' was registered with the National Office for Intellectual Property of Viet Nam. Within eight months, TraceVerified had launched its new software at a workshop called Electronic Traceability, held concurrently with the Viet Nam Fisheries International Exhibition (VIETFISH 2012) in Ho Chi Minh City.

In 2016, TraceVerified was established in order to deliver traceability services to the market. The main activity in TraceVerified is developing software to make traceability solutions easy for farmer-users to input data.

Outcome

TraceVerified has successfully developed and provided traceability systems for ten supply chains related to shrimp, catfish, blue-fin tuna, rice, tea, sweet potato, frozen vegetable, dragon fruit, fruit syrup, honey and cashew-nut products with the participation of ten food producers and farmers.

In July 2015, TraceVerified participated in SLUSH IMPACT 2015 (Viet Nam) and was selected as one of the top three projects for a chance to participate in the international SLUSH conference November 2015 in Finland (http://slush.hatch.vn/recap).

Stakeholders and partners

The horizontal impact (Figure E2) along the value chain that implements electronic traceability affects:

- Exporters: improved credibility with international buyers; ability to create and sell value-added end products; ability to increase revenues; enhanced product chain management capacity;
- Small producers: more stable procurement, stable production, improved sources of income;
- Farming households: very high probability as sales volume from their farms will increase thanks to better reputation and trust with intermediaries and small producers who buy from them (not always linked to price increase); more stable linkages to producers and exporters (security of contracts); self-confidence from becoming informed, engaged market players; and
- Consumers: transparent information on demand, peace of mind when buying products (especially important to Vietnamese domestic consumers).

Vertical impact on key stakeholder groups:

- Specific agriproduct sector: more positive perception of the market; improved brand equity; improved policy advocacy capacity;
- Authorities and policy-makers: policies more aligned and responsive to market needs; and
- Improved Country competitiveness, food security and social security.

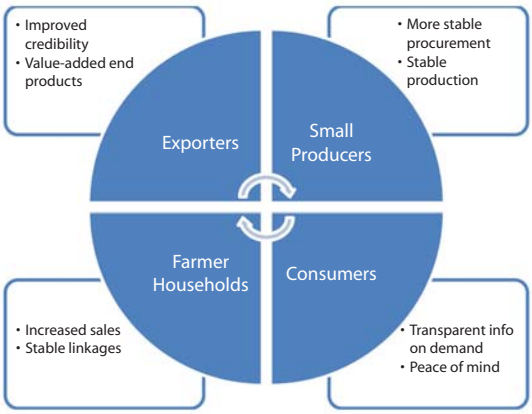


Figure E2: Impact of electronic traceability

Methodological approach

Definition

Traceability is the art of collecting information on food items so that their complete history can be recreated. This helps to verify information at all points in the chain of production and consumption. It shows whether the supplying company has done well in producing high-quality products. It shows whether the products have been under control along the whole chain. And it eases the legal burden on importers to document source information. Electronic traceability adds the strong advantage that the data can be accessed whenever required on productive processes while walking through the warehouse or checking on the packing line.

The only challenge with traceability is that it is a system of claims. While electronic traceability systems are more secure, fraud can still happen. The real value is generated when information kept in a traceability system is verified, i.e. when an independent body with a testing laboratory and field offices makes sure that the data from producers are correct.

TraceVerified is a paperless, user-friendly application for various aquaculture supply chains in Viet Nam. It ensures end-product quality, hygiene and it meets requirements by buyers, importers, importing countries' regulatory bodies and consumer associations.

TraceVerified collects and transports verified information from food producers to food buyers and it allows buyers to verify product information independently and conveniently.

TraceVerified helps to:

- Provide an electronic traceability system based on current production processes in food and agriculture businesses through all stages of the supply chain;
- Meet traceability compliance requirements of the major importing blocks such as the EU, USA, Canada, Japan and others;
- Easily track and identify any food item starting at any point and going in any direction of the supply chain;
- Trace and recall food if necessary to efficiently manage risks for consumers and brands;
- Reduce risk in the global food trade by minimizing the impact of contamination in the food chain;
- Control the information exchanged within each industry sector in the production chain including hatcheries/nurseries/farms, trading, processing, storage and export;
- Communicate verified information about food hygiene, safety and quality as a market differentiation factor;
- Employ ISO15459 certified, globally unique identification instead of local identification schemes that are not unique;
- Facilitate border clearance of products through the transparent delivery of information to border officials;
- Reduce cost, time and eliminate errors in paperwork; and
- Closely manage production procedures using information technology.

How does TraceVerified work?

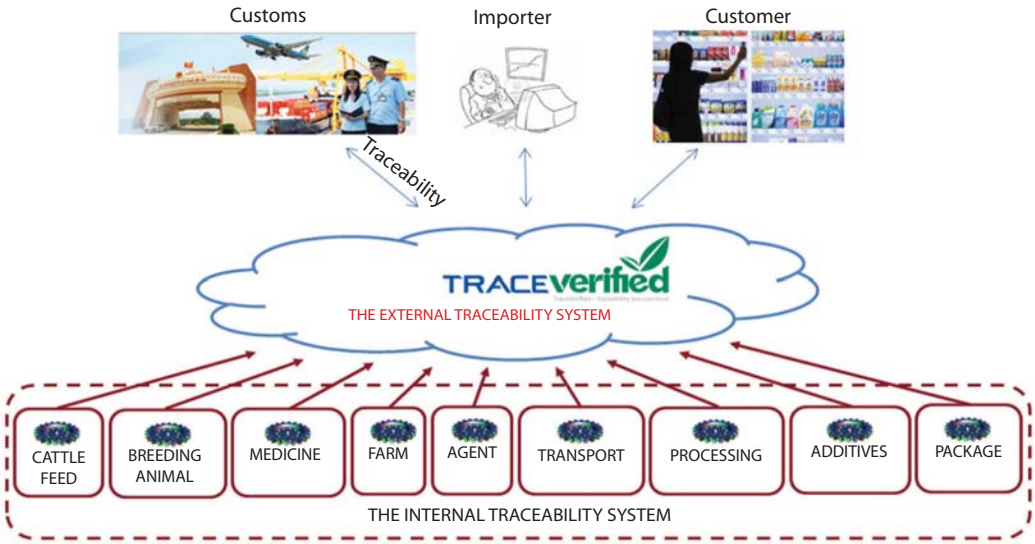


Figure E3: How TraceVerified Works

The information is digitized and stored on the server of the TraceVerified system. The data fields are customized according to user demand. The principles of traceability involve one previous step – one following step. This information is then encoded into a barcode and QR code (for each type of product the production batch has a different code) to stick on the products. The TraceVerified report is accessible through any kind of smartphone. No additional software is necessary. The report is immediately shown on the screen with one click. It can be used by custom officers to gain insight about the contents of a container, pallet or carton. Buyers and consumers can also read information by accessing 'Trace It' on the website www.traceverified.com (Figure E3).

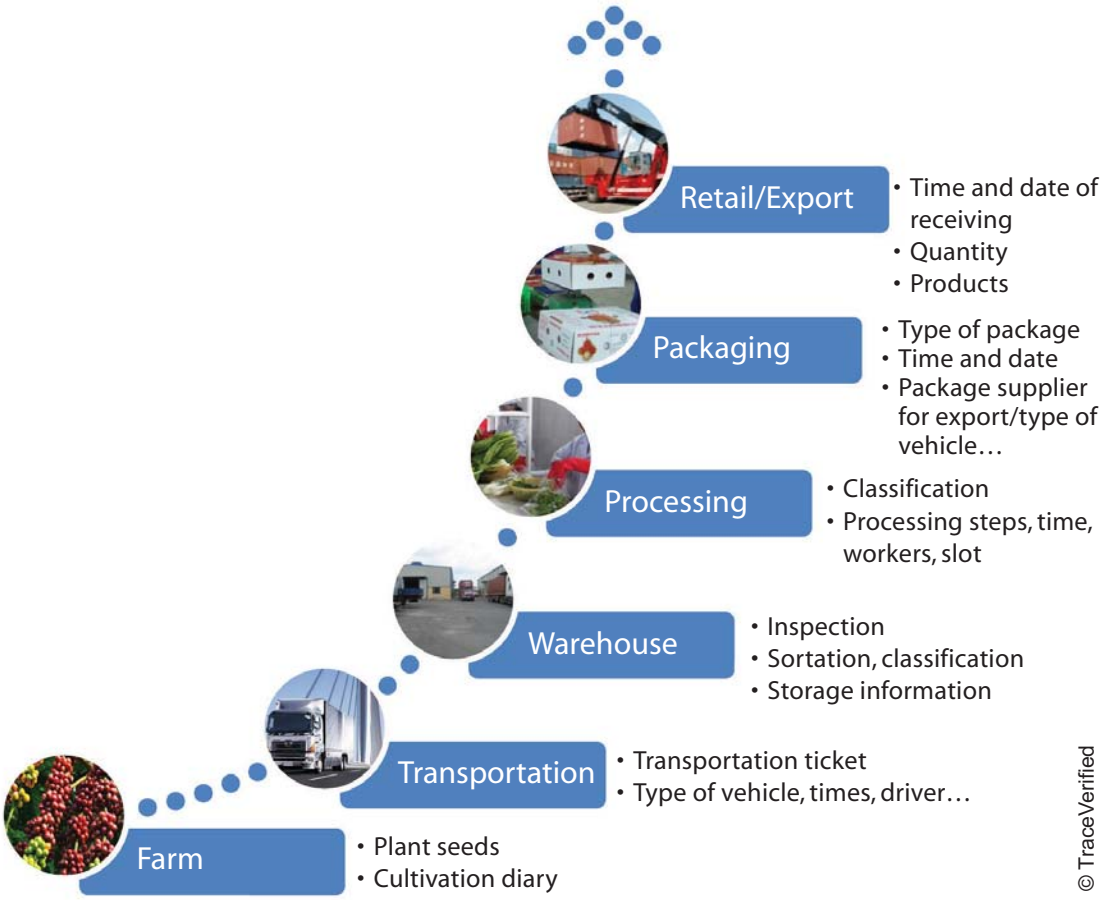


Figure E4: A simple model of a product supply chain and traceable information

Figure E5: Traceability stamp
On the right: GS1 Code
Upper line: T Code (optional)
Center: QR Code

The traceability stamp (Figure E5) is designed with three kinds of code. GS1 is used as the basis for the code of businesses. The T code is used for farmers and traders. Code traceability is in line with international standards and is unique worldwide. Information is accessible in real time.

The traceability report that a buyer/consumer can read after scanning a code is shown below (Figure E6).

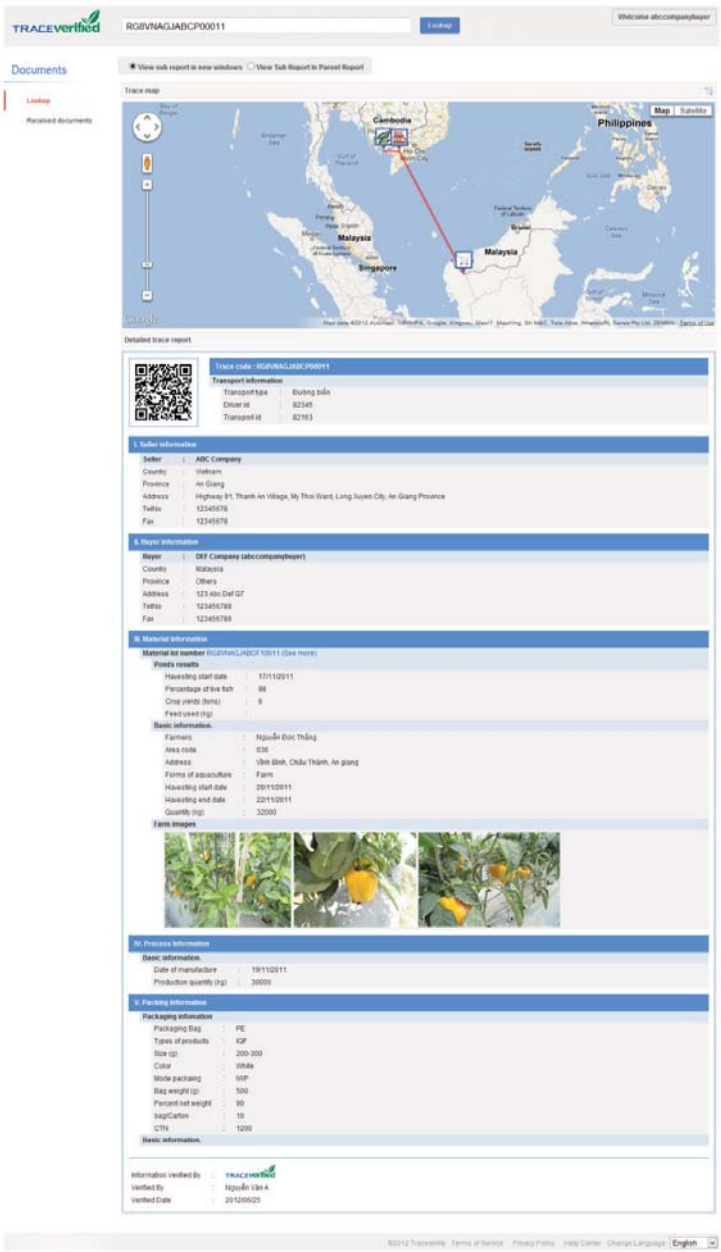


Figure E6: A sample traceability report

Operational environment

As a Web-based and smartphone-enabled IT system for external traceability, TraceVerified is built on Web technology using Microsoft technologies.

- Database: MS SQL Server 2005 or 2008
- Web Application: Asp.Net 4.0, IIS 7.0
- Server: Windows Server 2008

Reporting

Electronic traceability for more than ten supply chains related to shrimp, catfish, blue-fin tuna, rice, tea, sweet potato, frozen vegetables, dragon fruit, fruit syrups, honey, cashew-nut, organic vegetables and pork has been developed. Fourteen workshops to raise awareness on electronic traceability in general and TraceVerified in particular were organized, as well as 18 training courses on traceability, GS1, management and marketing skill for various supply chains.

In each value chain, a number of companies has piloted or implemented TraceVerified:

- Shrimp producers for export: Minh Phu Seafood Corporation, Quoc Viet Co. Ltd.;
- Pangasius producers for export: Nha Trang Seafood, F17 Joint Stock Company, Can Tho Seafood Import-Export Corporation (CASEAMEX), CAFATEX Seafood Corporation, Saigon-Mekong Seafood Co., Ltd.;
- Tuna producer: Ba Hai Co. Ltd.;
- Frozen vegetables: Bac Lieu Fishery JSC;
- Fresh fruit for export: Red Dragon Trading and Services Co. Ltd. (dragon fruit and lychee), Nam Thuan Viet Cooperative (dragon fruit);
- Canned fresh fruit juice for export: Nghe An Food Corporation (www.nafoods.com);
- Pork chain: Big C Ebon, Ha Tinh Agriculture Development project; and
- Fresh vegetables: Organica.

Summary of system components/requirements

Key components of the system:

- Staff who are responsible for checking and inputting information about the process (farm owner's name, address, day of harvest, name of feed, medicine…) to the TraceVerified system;
- Computers that connect to the Internet to input trace information to the TraceVerified system; and
- Printers to print the traceability code (QR code). It will be created from the TraceVerified system by specified software.

In some factories or farms with high production capacity, an internal traceability system to ensure the continuity of information flow is recommended.

Validation

- International community outreach by attending meetings and sharing experiences;
- The list of customers and expanding geographical outreach due to customer trust;
- Press information about TraceVerified;
- Attention and coordination among government agencies: the Ministry of Agriculture and Rural Development, Ministry of Health, Ministry of Science and Technology; and
- The coordination of provincial governments such as Ho Chi Minh City, Lam Dong.

Impact

TraceVerified's key beneficiary groups and their respective impact areas (Figure E7) are outlined below.

- SMEs: By implementing TraceVerified solutions, SMEs (from producers to exporter) across various value chains benefit from better internal management leading to improved business efficiency. Traceability enables these enterprises to reduce operational costs incurred in their business practices. In time, SMEs may benefit from better credibility and improved brand reputation in the market due to product traceability;
- Smallholder producers: Cooperatives of smallholder producers also experience material change. Implementing TraceVerified solutions enable producers to transparently communicate their cultivation methods to customers and retailers. By establishing stable market links, smallholder producers benefit from steady production and sales of their produce. This leads to improved income; and
- Consumers: Consumers can use TraceVerified to scan and access information regarding the origins, sustainability and hygiene of food products prior to purchase. They gain awareness about food safety. This results in better and more informed purchasing decisions.

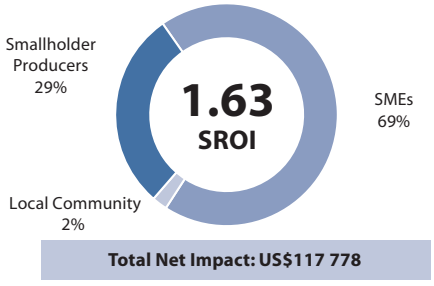
KEY INDICATORS (FY 2015)

6 SMEs experience Improved Business Efficiency. More than half of these SME clients are owned by women

85 smallholder producers in vegetable, fruits, port and poultry value chains benefit from improved income.

TraceVerified creates **US$2 450** worth of improved awareness about food safety.

SOCIAL VALUE CREATED BY IMPACT STAKEHOLDER (FY 2015)



Total Net Impact: US$117 778

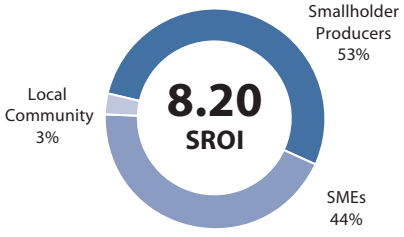
KEY INDICATORS (FY 2016, PROJECTED)

20 SMEs experience Improved Business Efficiency. More than half of the SME clients are owned by women

1 000 smallholder producers in vegetable, fruits, port and poultry value chains benefit from improved income.

TraceVerified creates **US$49 000** worth of improved awareness about food safety.

SOCIAL VALUE CREATED BY IMPACT STAKEHOLDER (FY 2016, PROJECTED)



Total Net Impact: US$1 798 251

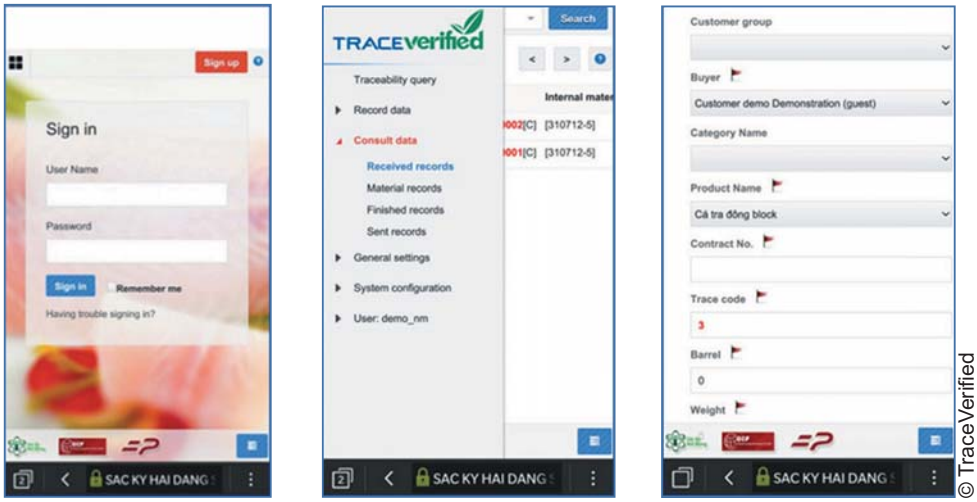
SROI (Social Return on Investment): A measure of how much social and environmental impact (in dollar figures) is created for every dollar invested into this program.

Figure E7: Impact assessment carried out by Impact Assessment Shujog Ltd., Singapore (in October 2015)

Innovations and key success factors

Innovative facts about TraceVerified:

- Low cost: free to information users (consumers, authorities, importers, buyers); annual cost for food producers ranges from US$1 000 to 2 000 (depending on company size);
- Minimum investment in hardware and software;
- Besides using computers and tablets for inputting data, farmers can text messages to send data to the system;
- The software also includes spreadsheets with prebuilt formulas as an alternative when buyers require data inputs to the TraceVerified system and Internet for online connection to the system is unavailable;
- Easy to use by small-scale farmers, with minimal instruction and training needed; and
- Possibility to scale up the initiative and to replicate within other supply chains.



© TraceVerified

Figure E8: Input form via smartphone

Limitations

TraceVerified has some limitations:

- It is difficult to raise community and enterprise awareness about the value of traceability due to limited resources;
- Because of low educational levels in rural areas, it is difficult for farmers to use the TraceVerified software;
- The set-up cost and annual fee for TraceVerified is perceived to be high; thus small enterprises/farmers with low price products cannot afford to use the service. Most products with premium prices can be stamped by TraceVerified. Other products need to be sponsored to implement electronic traceability;
- The requirement for traceability is not considered mandatory by the Vietnamese Government, therefore voluntary adoption of electronic traceability is limited to a small number of responsible producers; and
- System regulations and food safety standards in Viet Nam are not well implemented in practice, so it is difficult to accurately and reliably verify the information provided by food producers.

Lessons learned

Since the launch of the project four years ago TraceVerified has recognized:

- Verification is the most important thing when providing service;
- The interface needs to be friendlier with users, especially the data input;
- Security and safety of information systems and the Internet infrastructure should be ensured to enhance customer confidence;
- The demand for most agricultural and fisheries export products within Viet Nam and in the neighbouring countries is for raw or crude products, thus traceability is not perceived to be an urgent requirement;
- The whole food supply chain including producers, farmers, retailers and transporters needs to be involved in the TraceVerified system to ensure the accuracy and sufficiency of information flow;
- Food exporters in Viet Nam in general are not ready to provide transparent information about products unless there is associated pressure from customers, importers or the authorities;
- It is difficult to ensure complete traceability in small-scale agriculture; and
- Awareness of food manufacturers in Viet Nam about traceability and paperless trade is limited. They are still ignorant of the benefits and the importance of traceability for the purpose of paperless systems and trade facilitation.

Sustainability

TraceVerified can be scaled up regionally and globally, offering a complete end-to-end solution which tracks information about food sources, and makes that information openly available to the consumer at the point of selection in the retail environment. By encouraging farmers/producers to be more responsible, TraceVerified contributes indirectly to the sustainability of agricultural production in general.

Reliability and upscaling

TraceVerified plans to expand service to other agriproduct supply chains and advocate national policies for more comprehensive, enforceable traceability and quality assurance policies.

Prospects for the scalability of TraceVerified seem to be promising: Viet Nam's TraceVerified system can satisfy the latest requirements of electronic trace verification and therefore there is the potential to extend this tool to other sectors. In fact, this electronic trace verification platform has been applied to fish, shrimp, vegetable and fruit production and a complete programme of trace verification and labeling software for export products to the EU.

Many obstacles still remain before full implementation of paperless traceability systems will be possible. On the one hand, to carve out a niche in foreign markets, Vietnamese farm produce brands will need to provide reliable information. On the other hand, to stay competitive in the global market, Vietnamese businesses need to progressively adapt to changes in these markets, to apply information and risk management to production chains and be committed to applying advanced, international standard management. By doing so, businesses will gain customer trust and find opportunities to sell their products at competitive prices.

Besides, TraceVerified will also focus on:

- Expanding service to multiple fisheries and agriproduct supply chains;
- Advocating national policies for more comprehensive, enforceable traceability and quality assurance policies;
- Working with policy-makers to popularize electronic traceability systems among all food supply chains in Viet Nam; and
- Looking for new funding support to continue improving the TraceVerified app for customers' items and to bring the system to vulnerable small farmers in remote areas.

Conclusion

Traceability is not a trend but an evolution in the awareness and demands for food consumption by people. Food producers need traceability to meet international standards and global trade. Traceability using information technology tools to save costs and improve business efficiency. However, to use the services, farmers need to have certain knowledge about IT. There should be cooperation among several chains in the system for synchronization and control (verified) from each other in the entire system. The participation of socially impacting investors to improve the final product price will bring value to the entire chain.

The biggest benefit of TraceVerified is that the customer will be confident about how our company cultivates and takes care of the product in an organic way. Mr Tuan, Farm Manager, Organica (SME)

Traceability can bring a big benefit for the farmers – if the product can be traced then it will be more credible in the minds of consumers, farmers can build a reputation and a certified product can bring higher prices and security. Ms Nguyen Thi Anh Ngoc, Founder, Viet Rabbit Cooperative

For more information

Traceability Solutions and Services Joint Stock Company
E-mail: info@traceverified.com
Website: www.traceverified.com

Food Health and Safety Information Traceability System in China

Case study F

Objective

1. Monitor food quality throughout the whole process, discover and solve problems in a timely manner and effectively, and reduce the possibility of food insecurity.
2. Prevent the circulation of counterfeit commodities, amend the sales chain and protect company brands.
3. Make it easier for corporations to control the production process, to avoid overproduction and resource waste, and to decrease the cost of delivery.
4. The government can analyse the data from the Food Health and Safety Information Traceability System for better market regulation and monitoring.

Introduction

For most countries, food and agriculture are very important components of trade and economics, especially for developing countries where food supply is insecure and hunger is commonplace. The People's Republic of China, with a population of 1.3 billion, not only needs to address food scarcity, but also must pay attention to food quality and safety. Presently, China is one of the world's main producers of grain, fruit, meat, eggs and aquatic products. Hence food quality and safety in China are extremely significant issues.

In this context, the Chinese Government is actively promoting a food health and safety information traceability system (FHSITS). In February 2009, the Food Safety Law of the People's Republic of China was passed to clarify the requirements for the information system. In October 2015, the new food safety law made a more specific request concerning a 'Food Health and Safety Information Traceability System' (see Food Safety Law of the People's Republic of China [2015], chapter 42). In May 2013, the Ministry of Industry and Information Technology released a pilot programme for the FHSITS. The programme planned to construct the platform for the FHSITS within two to five years. In June 2014, the FHSITS was officially launched. The system, which considers food industrial enterprises as the main body, has covered six leading enterprises that produce formula powder for infants. In December 2015, the Information Record Specifications of Food Safety Traceability of Production Enterprise for Formula Powder for Infants was issued by the Chinese Food and Drug Administration. In this document, the government demands detailed information starting from the process of manufacturing to selling, which should last for more than three years. Consumers should be able to trace all of the information regarding the product, such as production source, transportation process, etc., by searching online. It is likely that this system will branch into other related industries. By connecting each of the steps, i.e. production, inspection, regulation and consumption, the FHSITS issues each food commodity with an E-ID (electronic identification) to track all of its information. The system can track the information from the end point to the starting point — from the consumer's dining table to the producer's farm. In addition, the system will establish a database for food quality and safety.

Methodological approach

Figure F1: Input form via smartphone

An example of the FHSITS for the dairy industry is given below (Figure F1).

1. Information collecting system for raw materials:
   – Create an ear tag for a cow using radio frequency identification (RFID) technology and record the cow's health condition, reproduction and disease history. This information will be stored in the production database to support the information system.
2. Electronic recording system in the production process
   – The manufacturing factory will record the food material production date, expiration and origin as a QR code, and then stick the code label on the package. Once the processing factory receives the package, it has all the information needed and can process the product as required. For the next step, the processing factory will add a new QR code to the original one, which contains new information, such as the product's name, ingredients and dates.
3. Delivery tracking system
   – Using RFID technology, the system can read the information on the truck (with GPS and a temperature detector) and the RFID tag on the food package, and then send the data to the FHSITS promptly. This can offer better inventory management and lower the cost of delivery.
4. System platform for basic information
   – By scanning the QR code (Figure F2), consumers can check the date, the manufacturer, certificates and ingredients. Consumers can also find credibility reviews, instructions for consumers, quality inspection reports for the main material and the final product, management system certificates, product certificates and websites of manufacturers. In future, the QR code will include all the information about every can of milk power, which can than be tracked back to its manufacturer's farm.

Figure F2: Tracking using QR codes

In general, the whole FHSITS process comprises:

- Raw material companies consult the information collecting system of raw materials for the production date of raw materials, the deadline for consumption, food source, producer, examining report and so forth. These companies will then record the information using the QR code and attach the code label on the packages of their raw materials. These containers will be sent to corresponding manufacturing factories are traced by the Delivery Track System;
- Manufacturing factories need to continue the traceability of information through the Electronic Recording System in the production process. They will check the information on the raw materials using their barcode data collection terminals once they have received the materials. They will then add new information, such as date of storage and suppliers, as a new QR code to the original one;
- After completing the productive process, the aforesaid container will be stamped with production time and additional information such as product name, starting date of production, end time of production, encapsulation and production equipment serial numbers recording of;
- Food factories can remove some information as long as they can ensure that the outgoing food can be traced back to the raw materials used;
- Consumers can obtain information by scanning the QR code on the food package to confirm their trust and confidence in the brand of food; and
- Companies can trace the production process and likely causes of food quality problems and recall the product in time in order to mitigate economic and image damage.

Validation

1. In June 2014, the Ministry of Industry and Information Technology together with other government institutions and companies built the FHSITS. It improves consumers' knowledge of food quality and safety and provides them with an authoritative way to check information on food products.
2. The FHSITS had added six infant formula milk powder pilot enterprises to its complement of participating companies. These corporations have accomplished all the technical modifications and improvements required. Their products, labelled with the QR code, have entered markets and contain up to 31 types of information inputting 42 008 200 data items to the public database (Figures F3 and F4).

© FHSITS

Figure F3: FHSITS website

© FHSITS

Figure F4: Phone app and information retrieval

3. The Food Traceability General Specification and the Food Traceability Code and Mark Specification have been approved by government departments. Combining experiences and practices, some relevant norms and standards for the industry, such has the System of Food Quality and Safety Traceability for Infant Formula Milk Powder Industry have already been drafted.

4. Consumers can now use their smart phones to learn about products, especially vegetables, in some supermarkets in China, like Carrefour. These supermarkets also regard their administrative control of food information traceability as a means of attracting customers.

Raising FHSITS awareness

The success of the FHSITS has led food manufacturers to realize its importance. Concomitantly, the government needs to raise consumer awareness about the system to encourage corporate inputs indirectly through consumer cognition and usage rate.

Constraints

The technology for establishing the FHSITS is complicated and consequently there are several constraints and difficulties for the system to be effectively replicated and widely promoted.

1. The construction and application of related hardware, software and databases can be expensive, which might reduce companies' internal demand and positivity. In fact, the closer to the source the FHSITS is, the harder it is to implement, especially for information during cultivation and plantation. That is why the FHSITS for luxury food, such as birds' nest soup, is generally at a better level.
2. In the FHSITS, the digital information management is the core activity. Currently, when scanning the QR code scant information or only advertisments can be found, especially with regard to small enterprises.
3. It is clear that the information traceability system could encompass the entire supply chain which involves many enterprises. However some enterprises do not want to release too much information as they consider it to be classified corporate data.

Conclusion

Currently, as smart phones are widely used in society, consumers can track all the information on a food product using their phones and decide whether to purchase or not. This can effectively guarantee the consumer's right to information and choice.

For more information

E-mail: changlin@caict.ac.cn

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IRRI Rice Knowledge Bank

Case study G

IRRI AND THE NATIONAL AGRICULTURAL RESEARCH AND EXTENSION SYSTEM

Objective

The story of the Rice Knowledge Bank (RKB) initially with the International Rice Research Institute (IRRI) and then with national partners is an open-ended journey of bridging the information divide between research innovations and agriservice agencies and farmers. For IRRI it became a serious endeavour from the late 1990s. The RKB was an initiative by IRRI to create a clear channel between research and extension and to bring together its training materials. A key principle was one-stop publishing. Almost immediately IRRI began systematically working with national rice research institutions that face the same challenge. Examples from Bangladesh and the Philippines illustrate the country-specific story. Credible sources of knowledge that can be accessed by a growing number of agencies (public, private and civil) underpins the importance of knowledge banks. The IRRI RKB and associated products serve that role for some countries and national government-managed knowledge banks are pivotal for others. An indication of impact is initially considered at the research institution level through which knowledge is available to multiple agencies. There are challenges for IRRI and national institutions in flow of funding, institutional commitment and core mandate, IT server upgrades, updating information, competing projects, changes of leadership, responding to new communication technologies such as mobile phones and so forth. Each potentially threatens steps forward and in some instances has resulted in inactive knowledge banks. IRRI in its efforts has emphasized on reliable content that can then go into many formats for extension services and farmers. In scenarios for the future it is not a single institutional undertaking. IRRI and national institutions will need to be responsive to new forms of partnerships that maintain consistency of content and encourage access through multiple channels that may reflect public, private and civil society initiatives.

Introduction

As an organization, IRRI's aim is to see significant and sustainable changes in the lives and health of resource-poor farmers from marginalized communities and ecologies.

The challenge in achieving this across Asia and Africa for farmers who use multiple dissemination channels for knowledge of technology options and their connection to input and output business services, is immense. This challenge also falls into the backdrop of rural communities transforming rapidly with shortages of land, labour and inputs and a growing diversity of agriservice agents from public, private and civil society organizations, who have inadequate access to progress in research. IRRI's effort to bridge this gap started in the 1960s through its research and education programme to develop new technologies and to build the capacity of national research and extension partners in-country. A key to achieving impact from the research-based knowledge is improving the knowledge-base of extension workers and equipping them in their day-to-day engagement with farmers. The knowledge needs to be location-specific, in the local language and in formats (e-learning course, SMS texting, videos, kiosk call services, extension leaflets, radio scripts or mobile phone messaging) that are useful for extension professionals in public, private and civil society organizations.

Advances in technologies come from different sources and collating knowledge that is up-to-date, credible, timely and in formats understandable to farmers is a major challenge. Equipping multiple extension services with these

messages to establish the feedback loop with ongoing research is an added layer of complexity. ICT platforms for knowledge exchange and learning are a means for bridging the divide and have been major game changers. The response by IRRI to the challenge of translating research into extension communication for giving farmers access to knowledge on new technologies was initially internal. In this context IRRI built the IRRI Training Bank that became the IRRI Rice Knowledge Bank.[9] This extended to working with national research/extension institutions for building their own knowledge banks in local language. A key principle in the development of the RKB was single source publishing, which allowed credible content to be used in multiple communication formats. The RKB approach was to enable collation of rice-based knowledge that was country-specific and reflected national agricultural authority. This was then made accessible to ICT intermediaries and rural services agencies for using as is, or repackaging for dissemination to farmers.

This chapter tells in brief the story of the RKB for IRRI and two countries – Bangladesh and the Philippines. Within IRRI, the Bangladesh Rice Research (BRRI) and the Philippine Rice Research Institute (Philrice) the concept of an RKB for rice-based knowledge that is credible, practical and provides a source for multiple extension services and agriservice professionals has been established as an essential activity of the respective institutions. For some country partners the country RKB is languishing or has been trapped within a project. In such cases the fall back onto more general knowledge or the country portal within the IRRI RKB has been more important. Statistics show positive use. The prevalence of ICT and multiple providers has helped research institutions to more clearly define their boundaries and to consider themselves a link with a responsibility to provide credible content.

Phase development within IRRI

The initiatives within IRRI for a knowledge bank began with a small group within IRRI itself, which responded to the challenge of research findings being locked in peer-reviewed journals and not being translated into messages that built the capacity of extension professionals who would relay the information to farmers. The IRRI Training Bank was formed which later became the IRRI RKB. It served to provide recommendations for the IRRI farm itself, simple information products on growing rice and archiving of training manuals. The target audiences were extension personnel or students of agriculture or teachers of agriculture in colleges. For extension personnel there were also materials that could immediately be localized in local languages for farmers. The RKB also included e-learning modules and a rice doctor for diagnosing crop pest and nutrient issues in the field.

The IRRI RKB was made available to countries in a CD format that could support national training programmes. The shift to web-based information coupled with CD downloads and the concept of one-stop publishing made knowledge more widely accessible. The CDs were widely popularized through IRRI country programmes. At the same time the IRRI team began to work with national institutions in collating their own rice-based knowledge or choosing to translate material from IRRI for their own country portal. Initially the country portal was managed directly by the IRRI RKB team. Key examples are the Philippines RKB effort in the late 1990s and the Bangladesh RKB from 2002 onwards. These are discussed as specific case studies later. The IRRI RKB team has also delivered IRRI training courses and served the rice research institutions of national

[9] Atkinson, A.D. & Bell, M.A. 2003 a,b; Amerasinghe, N. 2003; Bell et al. 2004; Shires, D. 2001.

partners. Figure G1 shows the successive evolution of the IRRI RKB platform. It is not a static product and has needed to adapt over time to changing Internet capability.

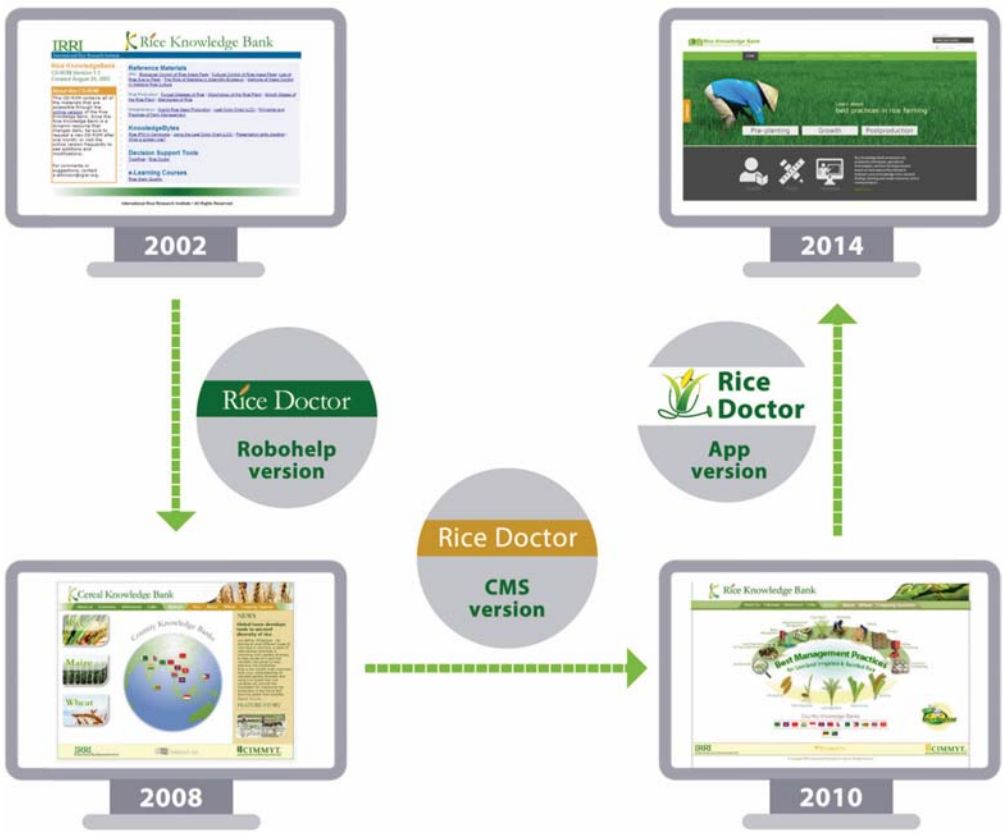

Figure G1: RKB/Rice Doctor timeline

2002: The first RKB, a selection of IRRI knowledge. IRRI's RKB project worked with national agricultural research and extension (NARES) partners to introduce good rice knowledge management in 13 countries (country RKBs) from Asia. The Rice Doctor was developed and became accessible online using the Robohelp software.

2008: The importance of national research is recognized and national RKBs are created behind each country flag. The concept is expanded to include wheat and maize in collaboration with the International Maize and Wheat Imorovement Center (CIMMYT). The Rice Doctor migrated to an open source Content Management System (CMS) platform.

2010: The content is organized behind 'Seed to Market' and 'Growth Stages' icons. Each area is organized and approved by a senior scientist. The management of country RKBs became a country-level activity.

2014: The major content of the RKB was overhauled and redesigned to effectively cater for extension agents, private consultants and other intermediaries working directly with farmers. The Rice Doctor was developed into a mobile app and the beta version was released in the middle of 2014.

RKB Google Web Analytics
Date Range: Mar 1, 2008 to June 1, 2016
Users: 2 887 798
Pageviews: 14 206 732

RKB Apps Installations
Date Range: April 27, 2015 to June 1, 2016
Android: 2 524 unit installs

RD App Installations
Date Range:June 2014 to June 1, 2016
Android: 5 919 Unit installs
iOS: 12.3 k unit installs

Quality Seed Course Google Web Analytics
Date Range: Feb 1, 2012 to June 1, 2016
Pageviews: 200 900

Figure G2: Statistics for the IRRI RKB

For IRRI, the development and management of the RKB and associated knowledge support products requires a minimal team of three people (evaluation, content development and management, cytoplasmic genetic male sterility [CMS] management) for maintenance and upkeep. The content development person has the important role of drawing in technical expertise within the organization itself and from projects in which new technology and communication products are being developed. This is a minimum maintenance requirement. Upgrades or new products or country knowledge bank development with national institutions or building the links for knowledge pathways through the emerging multiple actors in dissemination requires additional investment and is covered within broader projects.

Capacity development for the IRRI RKB and associated knowledge products is continuous. It is recognized that information technology platforms are changing rapidly. Initially the RKB was housed on the Internet with dissemination to countries through CD. Now the Internet is the repository that supports more and more mobile applications. In the environment the approach of the IRRI RKB team is to build capacity in an ongoing manner for awareness of emerging trends and technologies but also to have a model that recruits for major upgrades or new platform or product development.

Working with national partners to develop their own RKBs

Rice food security is a priority issue for national governments. Shortfalls in production can accentuate food prices, which can in turn impact the government itself. National rice research institutions are responsible for the rice-based system recommendations for their respective countries. Recommendations for farmers regarding variety choice for the diversity of ecosystems, for crop management from seed to market and pest management demand credible knowledge by the Ministry of Agriculture. Credible recommendations from scientists and informed extension services underpin the public system and more and more of this feeds into diverse actors for extension of rice knowledge for farmers. Country-specific RKBs, as for IRRI, are effective ways to collate and maintain up-to-date rice production guidelines for extension intermediaries and farmers. IRRI, with its experience of developing and maintaining its own RKB, began almost at the same time to work with national institutions. Over time IRRI has worked with countries in Asia, namely Indonesia, the Philippines, Viet Nam, Cambodia, Thailand, Lao PDR, Myanmar, People's Republic of China, Bangladesh, Nepal, Sri Lanka, India, Pakistan; and Africa, namely Mozambique, Tanzania, Kenya, Uganda and Rwanda.

The IRRI RKB has over the years developed a systematic approach to working with national partners for the development of their own knowledge banks, through workshops and discussion forums. Depending on IT capability, the country RKB may be located on an institute's server or the IRRI platform itself. Key components of country RKB workshops are:

i) Bringing together a wide range of stakeholders from government research and extension institutions and agricultural information services, civil society organizations and as available the private sector. The composition of participation is set through discussions with the lead institution.

ii) Exercises on priority extension materials to be developed for the RKB. The focus is on selecting appropriate material rather than developing and uploading everything.

iii) Management of the RKB itself and decision-making for the RKB on content.

iv) A vision of how the RKB will be used and viewed within five years.

v) Types of communication materials.

vi) Capacity development needs of actors in multiple channels.

vii) Authority of the RKB (use within the minister's office as in Bangladesh, while being hosted at the national research institute).

The workshop agenda has been developed as a module and is available at http://www.knowledgebank.irri.org/capdev/index.php/module-17-establishing-a-cereal-knowledge-bank, and is graphically represented in Figure G3.

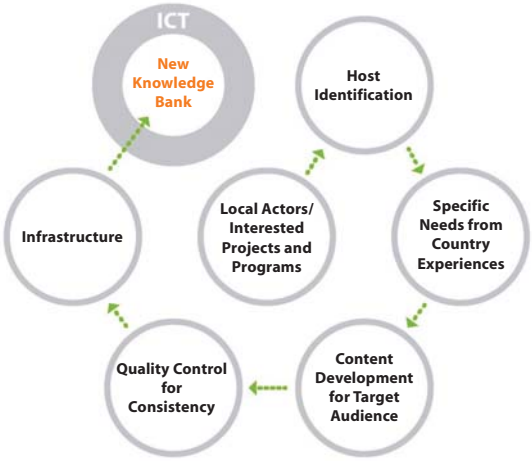

Figure G3: Steps to starting a new knowledge bank

Country knowledge bank case studies

Philippines and the Pinoy Rice Knowledge Bank (http://www.pinoyrkb.com/)[10]

In 2000, a partnership with IRRI started that focused on improving the capacity of PhilRice to improve this knowledge resource using more modern software (i.e. Robohelp) and training PhilRice personnel on the use of information technology to reach farmers. This partnership was further strengthened with the implementation of the Open Academy for Philippine Agriculture (OpAPA) in 2003, with ProRice evolving into Pinoy Farmers' Internet to cover other crops and livestock. The OpAPA programme broadly promoted the use of ICT for development of extension and, later, through the CyberVillage and K-AgriNet's Aurora e-Village projects, which are offshoots of the OpAPA, the use of ICT was further encouraged at the village level. In the course of this partnership journey that also involved local government units, state universities and other national and international research organizations and government agencies, more contents and services were added to the PhilRice Internet knowledge base. IT infrastructure was gradually improved, and more ICT training and promotion

[10] The term Pinoy relates to the Philippines or the Filipinos.

activities were conducted. From ProRice, it developed into Pinoy Farmers' Internet, and, finally, Pinoy Rice Knowledge Bank[11] (Figure G4).

In November 2010 the Pinoy Rice Knowledge Bank was officially launched to support the Philippines' Rice Self-Sufficiency Program as a reliable and easily accessible source of knowledge on science-based rice and rice-based farming mainly for extension intermediaries. The launching came after years of testing, learning and enhancing this knowledge resource that started as ProRice in 1999. It was a small Japan International Cooperation Agency (JICA)-funded project then, jointly implemented by the Development Communication Division and the Information and Communications Technology Division of PhilRice and born out of exhaustion from the task of going through numerous, disorganized references to respond to information requests and development of information materials. ProRice was an HTML-based platform that offered only three key sets of information: the how-to's of rice production; the principles and related concepts behind rice production; and other useful information related to rice (e.g. province-specific production data, rice-based food products and images).

An important exercise completed by PhilRice in the lead up to the release of the Pinoy RKB was the harmonization of PalayCheck (an extension and training programme with printed materials) with the Internet content. The outcome was consistency of content across communication platforms.

© ProRice

© Pinoy Rice Knowledge Bank

Figure G4: ProRice and Pinoy Rice Knowledge Bank

Since its launching in 2010, the Pinoy Rice Knowledge Bank has continuously undergone changes and improvements in content and technical specifications to better cater to a broader set of users, such as the younger generation, those in the media, agricultural researchers and teachers, and progressive farmers. Rice knowledge is available in various formats (e.g. handouts, videos, images, audio clips, Powerpoint presentations), a chat platform has been added and translation of key sets of information into the four major Philippino dialects has been intensified. With ICT infrastructure still a challenge especially in the rural areas, the Pinoy Rice Knowledge Bank now also has an offline version that can be downloaded quarterly for updating.

Usage

The number of users and pageviews continue to increase as funds for promotion and enhancement of ICT-based resources have become more available (Table G1).

[11] http://www.pinoyrkb.com

Table G1: Number of users and pageviews of Pinoy Rice Knowledge Bank, 2012-2015

Year	2012	2013	2014	2015
Users	26 497	35 184	44 497	36 260
Pageviews	188 372	234 895	256 980	192 742

Note: The change in domain address from Pinoy Rice Knowledge Bank to Pinoy Rice was a major factor, including in-house challenges in connectivity, in the decrease in number of users and pageviews from 2014 to 2015 (source: Philippine Rice R&D Highlights 2013, 2015).

A recent study by Manalo and Frediles (2016) cites the following interesting findings gathered from 31 extension intermediaries:

- Those who read the information found in the knowledge bank shared the information with their friends and farmers the most, and sharing took the form of informal conversation, formal lectures/discussions and via short messaging services;
- All the respondents noted that Pinoy Rice was easy to find on the Web and to navigate, and that there was nothing offensive or unbelievable in its contents;
- Most of the respondents found the information sufficient and up-to-date, and the website attractive;
- The top five most-liked contents were rice varieties, videos, learning modules, rice and rice-based farming, with rice varieties as the most remembered and most helpful feature of Pinoy Rice; and
- Suggestions to improve the Pinoy Rice Knowledge Bank Web site included: (1) regularly update the content; (2) simplify layout further; (3) increase speed of downloading information; and (4) seek farmers' information needs to serve as guide in improving content.

Sample feedback from users are documented in the PhilRice Magazine (2015). A farmer, Jun Estrella, from Victoria, Laguna said of Pinoy Rice: "It helps me manage problems on my farm. It offers complete information on pest and disease management". Estrella related that many of his fellow farmers from Victoria have decreased pesticide use after learning from Pinoy Rice about beneficial insects. "Almost 60 percent of farmers here no longer use pesticide. This has significantly lowered our input cost. Pinoy Rice complements the work of extension agents" according to Estrella.

On the other hand, farmer field school facilitators Joely Reguindin from Zambales and Halley Heria from Iloilo use Pinoy Rice to download lecture materials. "Pinoy Rice provides not only handouts but also audio clips and videos, which I share with my farmers" Reguindin noted.

Truly, the Pinoy Rice Knowledge Bank has evolved into a useful knowledge sharing and learning platform to help improve rice production. However, as ICT continues to improve, new sets of rice knowledge are generated; and user information needs and access preferences change constantly as well. The enhancement of the Pinoy Rice Knowledge Bank must not stop to remain relevant. And, with the current 1:1 000 ratio of full-time rice extension agents to farmers in the Philippines, the Pinoy Rice Knowledge Bank continues to be a key player in helping to fast track the dissemination of consistent, accurate and easy-to-understand rice information and technologies.

Bangladesh and the Bangladesh Rice Knowledge Bank (BRKB)

In 2002, the idea of establishing a rice knowledge bank in Bangladesh was introduced by an IRRI-managed project – Poverty Elimination Through Rice Research Assistance (PETRRA). It coincided with the ongoing developments for the IRRI RKB.

Early discussions centred around the challenge of projects often producing extension and training materials to promote project-and developed new technology recommendations but these materials subsequently becoming unavailable within a short

period of the completion of a project. Popularizing the BRKB website that was initially hosted by IRRI was to upload extension materials from the PETRRA project itself. Capturing extension materials in the form of fact sheets, flyers and posters digitally was a fast way of ensuring that such products from a project were not lost and could be used or modified for institute activities.

The Bangladesh Rice Research Institute (BRRI), the host institute for IRRI in Bangladesh responded positively to the concept and agreed to work for establishing the Bangladesh Rice Knowledge Bank (BRKB)[12]. A coordination group was formed. It was led by BRRI's director of research with representatives from IRRI and two PETRRA partner NGOs. Ready-to-use extension content from various sources (the project, BRRI, NGOs) was checked for credibility, collated and tested with farmers for content and comprehension. Materials developed were also made available on CDs for dissemination to farmers and extension workers through two hubs in two regions.

In late 2004, the project extended with the support of another IRRI-managed project, Food Security for Sustainable Household Livelihoods (FoSHoL). Training field workers on rice production was requested by the NGO partners of the project and a fact sheet-based training module was developed. This training module has hence become the hub of all rice knowledge developed so far by the BRRI. There were ups and downs with the level of energy in the development process of the knowledge bank within the BRRI. With project support it moved fast but with no project not much happened in terms of inclusion of new content or improvement of designs of the site and so forth. But the use of the knowledge bank as the principal source of materials for handouts for conducting training remained.

In 2009 the BRRI received funding from the National Agricultural Technology Project (NATP) of the World Bank to further develop the BRKB. In addition to factsheets, different formats (flip charts on different technologies, leaflets, posters, videos, FAQs and answer book, important national statistics etc.) were added.

Dr Islam Uddin Mollah, Head of Training and Coordinator of the BRKB gave the following assessment on the impact:

> "Throughout the country rice production training is being conducted by the DAE extension officers (490 numbers) at the subdistricts. Most of the officers are using BRKB materials, especially the flip charts and the training module for farmer training. Many Union-level digital centres (4 500) across the country are making use of the BRKB to provide rice information to their clients.
>
> Since 2012 the total hit to the BRKB was 206 542 (as of 30 June 2016). The mobile app version of the BRKB that was launched in early May 2016 has received 25 000 hits. The Prime Minister's office rated BRKB as one of the top five Bangladeshi sites that is reaching farmers. These are very significant developments. In addition, the private sector players are also coming along with their various services including call centres (e.g. win-miaki signed a Letter of Agreement with the BRRI recently). This is in addition to the Agriculture Information Services call centre, a government agency. Each uses the BRKB as the source for accessing rice knowledge. Finally, many NGOs active in agriculture in Bangladesh also make use of the BRKB for knowledge materials".

[12] http://knowledgebank-brri.org/

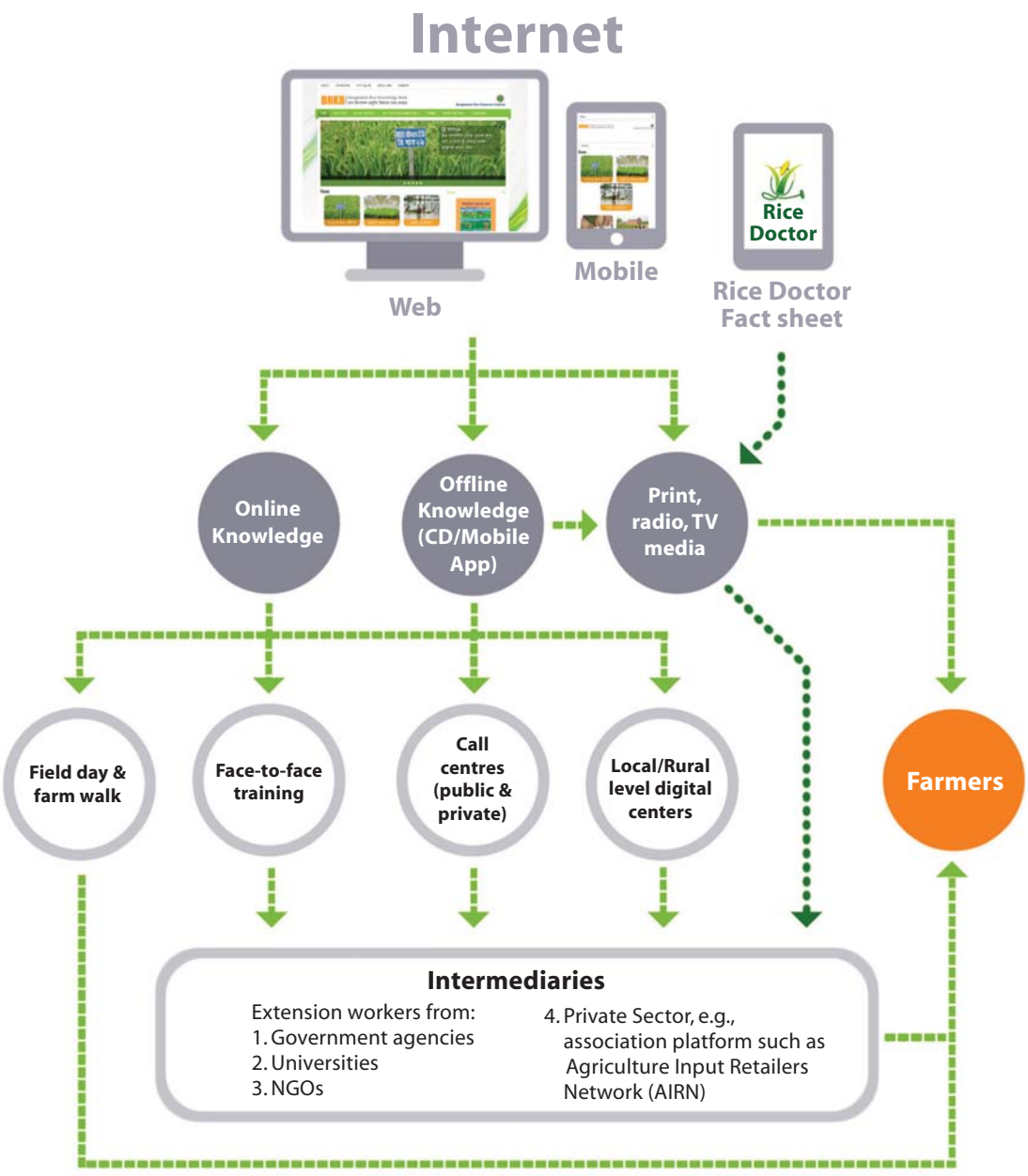

Figure G5: Bangladesh Rice Knowledge Bank dissemination pathways

Innovations and key success factors/constraints

The IRRI RKB and associated Rice Doctor are Internet and now mobile phone products that provide up-to-date knowledge for agricultural advisory professionals in public, private and civil society organizations. The opportunity was there to use the Internet to serve as a knowledge repository to support training and equip extension services. In the late 1990s the pioneer team at IRRI had that simple vision.

Several key success principles have emerged from the experiences of IRRI and the case studies of Bangladesh and the Philippines.

- An institutional home is essential. The RKB cannot be built simply with project funds but must at the same time be supported by institutional leadership. The homes for the respective RKBs are the IRRI Training Center, the BRRI Training Division and the PhilRice Development Communications Division. A scientist divisional approach may result in the product not being mainstreamed for the institute and being too fragmented and isolated ICT products;
- Credible content is the priority that can be adapted to the varying communication platforms of Internet, mobile phone, print, radio and video media. A platform may change but credible content can be moved from one platform to another;
- Authority is critical for credible content. In Bangladesh, the BRRI's director of research is the chairperson for the RKB team. Enabling a process for scientists to contribute to is important. It allows organizations across the country to confidently use the products for production initiatives and for training as well as to develop simpler farmer friendly products for extension;
- There is a mindset constraint – research projects across countries or within specific countries may not resource the RKB development (in this instance the IRRI RKB). This results in a loss of coherence and lost opportunity to, at a low cost, support both the IRRI RKB itself and the concerned national RKBs;
- Within national institutions there can be an IT capacity constraint. For PhilRice this has not been an issue but for a number of years this was a constraint for the BRRI. The IT server and uploading of new content was managed within a national project. Recently institutional capacity was strengthened that is an indication of the RKB being incorporated into the mainstream of the institution; and
- Open Access or licensing that supports coherence and transformation of products strengthens the position of the IRRI RKB or national RKBs in accelerating dissemination of credible content. For example, the fact sheets for pest management from the Bangladesh RKB can support special education products for training within the Agricultural Input Retailers Network.

The IRRI RKB story itself is of interest to any institution developing a Web-based (or now a mobile phone-based) product for extension. There is a need to move beyond being a project supported to being considered an integral institutional product. There are challenges that come with frequent changes of leadership, which can present a serious hiccup in continuity of product development and maintaining coherence of commitment across an institution. There is the challenge of keeping the RKB up-to-date in content. For the IRRI RKB, the web design, as seen in Figure 1, has gone through a series of changes. Integration with the look and feel of the other institutional products (e.g. the IRRI website) are also important.

Knowledge banks and the future

A credible source of knowledge in an RKB can serve as a hub within countries for dissemination of the information needed for coherent and rapid outscaling of new technologies. The outscaling agencies may be the Ministry of Agriculture itself in the Department of Agricultural Extension or Agriculture Information Services, or NGOs with an ICT for extension programme or ICT private sector companies which are adding value to information for farmers (examples are Digital Green using the IRRI RKB as the source for its virtual training institute). A government institution may have limited ICT capacity but its role in delivering credible content becomes a low-cost win for dissemination. A further example is the South-South video extension model of Access Agriculture (http://www.accessagriculture.org/). Its video library can be extended through local NGO video development for new technologies as promoted on the national RKB for scaling out within the country and potentially being used in other countries.

For the range of private sector, ICT for extension companies opening access to the national RKB is essential for converting into call centre services for extension. Legal protocol will need to be developed for this. At present a practice has been for an ICT for extension firm to hire young agricultural graduates or consultants to compile extension material. However, the recommendations provided for farmers may or may not resonate with the national research and extension efforts. Scaling up through multiple agencies is desirable but credible content is essential.

The examples of knowledge banks for rice as illustrated by IRRI and the case studies of Bangladesh and the Philippines are transferable and scalable for agricultural enterprises beyond rice. For example the process followed for the RKB can equally be applied to vegetables, livestock, fisheries and non-rice crops.

The role of IRRI is firstly ensuring coherence within its own international and country-specific sets of recommendations that come from its research. This includes the already available apps toolbox in the Rice Crop Manager and Rice Doctor and RKB lite. At the same IRRI can continue to work with national institutions along the same principles. It is not automatic that a new technology recommendation that comes from an IRRI-country research institution is automatically available within the country RKB. It is essential here that the IRRI RKB team is included within the IRRI research project to facilitate the links with the country RKB for dissemination.

Conclusion

The story of the IRRI RKB along with country RKB development is spread over 15-20 years. During that time IT technology itself has changed rapidly both in terms of price and accessiblity to computers as well as the transition from desktops to mobile phones and the emergence of social media. Concomitantly has come the opportunity for greater empowerment of rural communities. The early concept of the RKB was a respository that moved beyond the printed page and that allowed wide access to materials at minimal costs. The ICT RKB concept as pioneered by IRRI is a low-cost product, with low maintenance budget that can fit within the structures of national institutions as part of ongoing programmes. The credible content is adaptable to other platforms. For national partners, the evidence for BRRI in Bangladesh and PhilRice in the Philippines is that the RKB concept itself has become institutionalized.

A challenge which will be part of the ongoing story is the role of the RKBs as knowledge hubs for numerous and diverse platforms for large-scale dissemination of knowledge for best agricultural practices for improved livelihoods.

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Authors

Noel P. Magor, Head Unit Impact Acceleration and Training Center, International Rice Research Institute, Philippines

Poornima R. Shankar, Knowledge Management Specialist, IRRI, New Delhi, India

Ahmad Salahuddin, Consultant Networks and Partnerships in Development, IRRI, Bangladesh

Lauro, Atienza, IT Specialist for the Rice Knowledge Bank and Rice Doctor, IRRI, Los Baños, Philippines

Karen Eloisa T. Barroga, Chief Science Research Specialist, Development Communication Division, Philippines Rice Research Institute

Islam Uddin Mollah, Principal Scientist, Head Training Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh

Jerome Barradas, Junior Knowledge Management Specialist, IRRI, Los Baños, Philippines

For more information

rkb@irri.org

Smart Water Management in Bangladesh

Case study H

Objective

This paper describes the application of ICT tools for groundwater management in the Barind Tracts of Bangladesh. It is based on a case study conducted by the Centre for Environment and Geographical Information System (CEGIS), Bangladesh. The Barind Tract Multipurpose Development Authority (BMDA), which is responsible for agricultural development in the area has recently adopted prepaid meter systems with smart cards for water service delivery to the farmers. This is a radical shift from the conventional water delivery system and the adoption of this technology in water management is expanding rapidly. Details of the evolution of this ICT application, the hard and soft infrastructure needed for its adoption, management requirements and compatibility of the technology with the local farmers are hazy. In addition, how this technology has impacted groundwater management and its sustainability are also not well documented. This paper aims to fill these gaps.

The objective of the paper is to analyse the impact of the introduction of ICT technologies in groundwater resource management in Bangladesh and demonstrate its applicability for sustainable water management. It provides information on the physical and policy context that led to application of this technology, its impact on resource use and changes in water delivery services to farmers. The analysis contributes to improving management of groundwater resources and provides data and information for replication in other parts of Asia. In addition, it is instrumental in providing understanding of the capabilities of ICT within the water sector.

Geographical coverage

The BMDA service area includes the Bogra, Dinajpur, Ranjpur and Rajshahi districts of the Barind Tracts in Bangladesh. The BMDA has already installed more than 14 000 government-managed deep tubewells in the area, which are now gradually being transformed into prepaid metered systems. This technology is rapidly expanding to other parts of Bangladesh and other agencies involved in groundwater management. It potential for has national coverage and full-scale adoption is currently underway in areas where electrical pumps are being used for groundwater extraction.

Introduction

Context

Groundwater resources are the backbone of the rural economy in Bangladesh and sustainable management is prerequisite for improving rural livelihoods, poverty reduction and food security. Agriculture still accounts for most employment in the country although the agricultural contribution to the GDP has been declining recently. Except in the monsoon season, agriculture in Bangladesh largely depends on groundwater irrigation. About 70 percent of groundwater is extracted out of shallow tubewells and the remaining 30 percent are deep tubewells. The deep tubewells are mostly installed and managed by government agencies, whereas most of the shallow wells are privately managed. In the Barind Tracts, the socio-economic impact of extracted groundwater is considerable. Over 1.5 million farmers have already benefited from the tubewell programme. Deep tubewells are the main driver of the rural economy in this part of Bangladesh.

Challenge

Despite the socio-economic benefits of the tubewell programme in the Barin Tracts, the sustainability of the groundwater resources has been threatened from both financial and environmental perspectives. Poor cost recovery in the government-managed tubewells, increasing energy consumption, overextraction of groundwater resources, inefficient water use and increasing irrigation cost to farmers have all contributed towards poor performance of the groundwater sector. Several financial, managerial and administrative control measures were introduced in the past in response to these problems, but without any major success. A more radical innovation for water control was needed to address the problem.

Response

The BMDA decided to introduce ICT technologies to meet this challenge. The main reason being that this would help the BMDA to sell water on a volumetric basis and ensure full cost recovery. Accordingly, the BMDA introduced prepaid water metering systems with smart cards. The gravity-based open canal water distribution system was also converted to a pressurized buried pipe system to ensure on-demand volumetric water supply to farmers.

About the initiative

The initative started after several trials and retrials for groundwater management in Bangladesh. This initiative however should not be seen on its own, but rather within the broader context of ICT applications in other economic sectors as well as the emerging policy context of ICT application. Bangladesh adopted an ICT policy in 2009 that encouraged application of ICT in environmental management, for efficient resource use and to improve service delivery, transparency and accountability. This encouraged wider application of these technologies including for water management. Access to electricity in rural areas has also helped in wider application of ICT technologies in water management.

The technology used is simple, compatible and transparent. Farmers receive a user smart card embedded with their photo, name and telephone number as well as other details. Farmers can recharge the smart cards through vending machines from a dealer as needed. The vending machine dealers are connected with the vending stations at local BMDA offices. To irrigate, the farmer inserts the card in the meter slot, selects the irrigation time and the tubewell delivers the volume of water requisitioned. Alternatively, farmers can buy coupons from a BMDA office or its dealers, who gets a 5 percent commission on the value of coupons sold. They hand these to the pump operator who then delivers water for the numbers of hours paid for. The whole operation is regularly monitored and vigorously managed by the BMDA.

Outcome

The application of the prepaid system with smart cards has been very successful and it is expanding. The net outcome has been an almost 100 percent fee recovery, farmers have access to on-demand water supply on a volumetric basis, overall groundwater extraction has been reduced owing to efficient use of water and overall energy consumption has declined. All these factors have encouraged application of this technology in surface water-based irrigation systems too. More recently, the Asia Development Bank has been assisting the Bangladesh Water Development Board (BWDB) in rehabilitation of the Muhuri Irrigation Project (MIP) with similar technologies.

Stakeholders and partners

The BMDA is the pioneering agency for the introduction of smart card systems in deep tubewells in Bangladesh. The agency is engaged at all institutional levels in management and services for the application of these technologies. The BMDA has collaborated with Weishing Electronics Co. Ltd. and a local agent Sanakosh Associates for installation of these technologies. Bangladesh Agriculture Development Corporation (BADC), another agency for deep tubewell management is also rapidly expanding this initiative. Dhaka Water Supply and Sewerage Authority (DWASA) has started piloting of smart card systems for drinking water supply. The Bangladesh Government has high-level policy support for application of the prepaid metering system with smart cards. With introduction of this technology to surface irrigation schemes, stakeholders and partners in this initiative are expanding.

The primary users of the technology are the farmers using the deep tubewells for irrigation in the Barin Tracts. On-demand volumetric water delivery and payment mechanisms make this system very attractive to farmers and thousands have already benefited from the initiative. The vending machine dealers are another group of stakeholders. The dealers receive the vending machine and prepaid cards from the BMDA local offices and farmers recharge the cards through these dealers. Industries manufacturing the PVC pipes are another group engaged in the process. Application of prepaid meters requires buried pipe water delivery networks to ensure that each farmer has direct access to the water she/he pays for. Local dealers selling these pipes and skilled labour engaged in pipe laying and fitting are equally important partners.

As application of these technologies is rapidly expanding to include drinking water supply and surface irrigation schemes utilizing low lift pumps, millions of farmers will benefit from the initiative in the near future.

Methodological approach

Requirements

The set-up and implementation of smart card systems require the following:

- The identification and selection of the supplier for both hardware and software;
- The identification of vending machines and vendors, installation of necessary hardware and software: prepaid meter, vending station (VS), mobile vending unit (MVU) and system master station (SMS);
- Conversion of open canal gravity-based water distribution to the buried pipe pressurized delivery system;
- The exchange of knowledge and information with farmers; and
- Coordination with governmental and other organizational partners.

Personnel

Different persons are involved at different institutional levels of the BMDA to support this technology. At the field level, officials keep the vending stations (VS) and facilitate the operation of vendors' mobile vending unit (MVU) that provide services for recharge of farmers' smart cards. The VS is connected with the System Master Station (SMS) that gathers all information from the VS (payment, water withdrawal, operation time etc.) and is operated by headquarters personnel.

Capacity development/training

This initiative was a radical shift in water management technologies and required new capacity at all levels of the BMDA as well as for farmers' groups. Training was provided in both hardware and software aspects of the technologies dealing with operation of VS, MVU, SMS and the overall monitoring systems. In addition, farmers were also trained/instructed on how the system works, including how and where to recharge, how to withdraw water and so forth. The technology is very user friendly and even illiterate farmers are able to learn about its application in a very short time.

Infrastructure and system requirements

Different types of hardware and software are needed in ICT-based groundwater monitoring and management such as: (i) SMS, (ii) VS, (iii) MVU, (iv) SC (smart card), (v) CR (card reader), (vi) CP (card printer) and (vii) the prepaid box (Figure H1).

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Figure H1: Equipment used in ICT-based water management

Key aspects of system operation are:

- For the prepaid metering system every farmer owns a ***smart card*** which is embedded with his photo, name and a user number which is provided by the BMDA;
- For every pump station, the BMDA uses a ***prepaid meter*** with an LCD display. All the prepaid meters, air valves and start control units need to be installed in each water pump house;
- Each local office has a ***VS*** and each vending dealer has an ***MVU*** for facilitating the charging of farmers' cards;
- After one or two days a BMDA official visits the pump station and inserts his ***checking card*** in the meter's slot; the meter automatically uploads all information related to the previous pump operation;
- For continuous updating and monitoring of the collected data, all VS are connected to an ***SMS*** located at the BMDA's head office through which the head office automatically receives all vending information. The daily sales report, weekly consumption report, dealer-wise sales report, water abstraction volume and so on can be generated from the SMS. The overall control of the VS is maintained through the SMS; and
- In the farmers' fields, buried piped pressurized water delivery systems are essential.

A flow chart of the system's operation is shown in Figure H2.

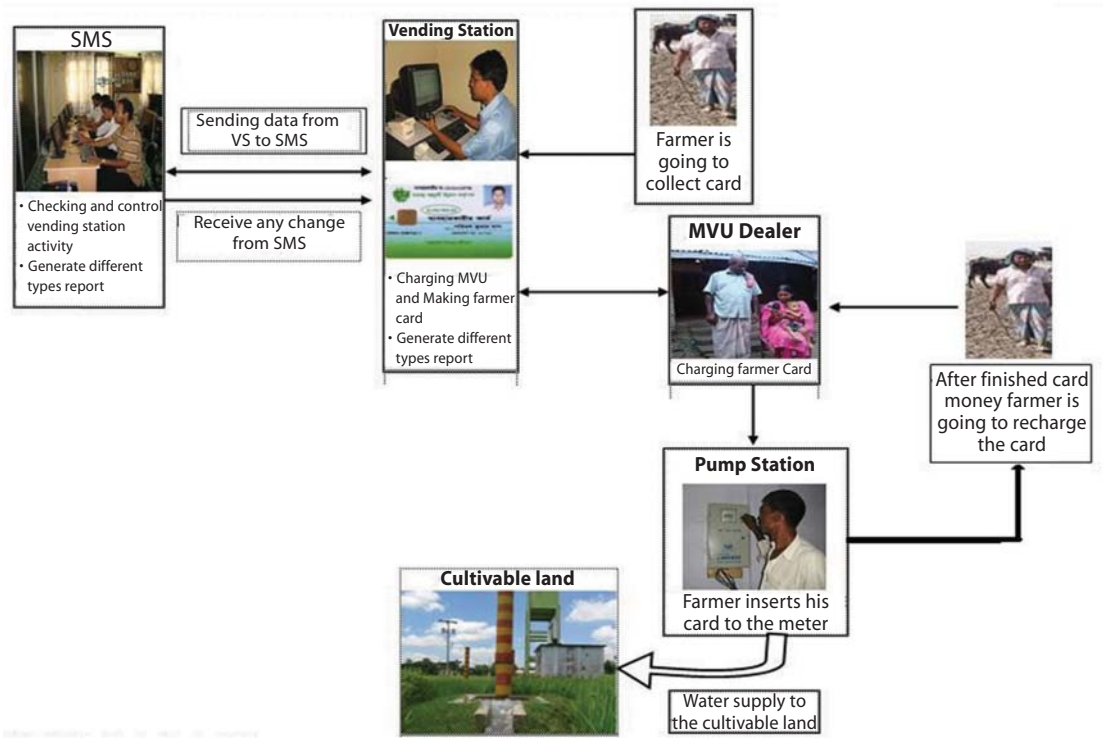

Figure H2: System operation

BMDA officials use a central server (the SMS) to store all information data, e.g. user information, charging information, meter charging with the user card etc. BMDA officials use database software called the *Payment Management System (PMS)*. The server computer is established at the BMDA's head office. Every Upazila (administrative region) office contains a *VS*, which is a computer and connects with the SMS through a telephone line. The VS is used for charging or uploading the meter information. To collect information transmitted from the VS to the SMS BMDA officials use telephone lines. This procedure is called telephone networking or the *Virtual Private Network (VPN)*. BMDA officials create a dial-up connection for the VS and use the telephone line that connects the VS with the SMS. An official who is operating the VS uploads the data or charges the user card.

Impact

The major impact of the ICT application in groundwater management in the Barin Tracts has been that this has ensured full cost recovery of the systems. This leads to a chain of other effects, i.e. full cost recovery means that the system provides 'on-demand' water delivery to the farmers. On-demand water delivery ensures increased agricultural production and productivity leading to increased income for the farmers. This in turn increases farmers' capacity to pay for irrigation which helps the BMDA to achieve full cost recovery.

The net result has already been demonstrated by successful agricultural transformation in the Barin Tracts. Cropping intensity is over 225 percent in this area and the average yield of boro (winter) rice is above 4.5 tonnes/hectare.

Some additional benefits brought about the technology are:

- It has reduced irrigation cost to the farmers. For a typical boro rice crop, the cost of irrigation is about 2 000 taka per acre, whereas the same for tubewells without smart cards is about 3 000 taka per acre (US$1.00 = 0.013 taka). For diesel pumps, it is as high as 5 000 taka per acre. Application of the technology therefore has reduced farmers' total production cost and helped to maximize the net profit;
- Another impact has been in the purview of water management. As farmers have to pay for water, they are practicing more efficient and improved water application methods. This will reduce overall water withdrawal, help to prevent saltwater intrusion and minimize overextraction of groundwater resources;
- A third impact is realized through reduced energy consumption. This will have implications for climate change impact mitigation; and
- Application of ICT has ensured both financial and environmental sustainability of the groundwater economy in Bangladesh.

Innovations and key success factors

ICT has been responsible for rapid economic transformation in recent times. ICT-related policies have become mainstream economic policies for underpinning growth and jobs, increasing productivity, enhancing delivery of public and private services, and achieving broader socio-economic objectives worldwide. ICTs and the Internet are seen as a major platform for research and innovation across all economic sectors (OECD 2012). While ICT has already been widely used in other sectors of the economy, its entry into water management is relatively new. Cost recovery in groundwater has always been a key challenge for government authorities and ICT has

been successful in this context as demonstrated by the BMDA case.

The introduction of ICT has generated several innovations in water management. It has allowed demand-driven water delivery systems on a volumetric basis to be tied to payments. It therefore affords protection of water rights for individual farmers. It is based on full cost recovery principles and thus ensures financial sustainability of the system. It establishes a fair water pricing system. Another key factor is that the system is transparent. Farmers are assured of water based on their payment. It has increased BMDA's accountability to them.

Other factors that have led to successful application are:

- Favourable policy and institutional environments: As mentioned earlier, the Bangladesh Government adopted a national ICT policy in 2009 that encourages ICT application in all sectors of the economy. This helped the BMDA to adopt ICT for groundwater management;
- Compatible technology: The technology in use is simple to operate and maintain. BMDA management finds the hard- and software components easy to use. Even illiterate farmers are able to use the system with minimal explanation;
- BMDA commitment: The BMDA is fully committed to this technology and given the need for full cost recovery of the systems. It has established effective service delivery and monitoring systems; and
- Social acceptance: In a recent survey, about 44 percent of the farmers rated the technology very good whereas 37 percent considered it to be good. About 17 percent thought it was moderately good whereas 2 percent rated it as bad. The high degree of social acceptance has been a key factor in successful adoption of the technology.

Constraints

No major constraints have been reported so far except for irregular electricity supply. However, the water delivery arrangement limits the flexibility of water distribution to farmers' fields. The distribution network is suitable only for bulk water supply, as farmers paying will have direct control over the water they pay for. The discharge of the tubewells is usually higher than 30 litres per second and all water is diverted to farmers' fields using the card. So, even a small plot of land will receive bulk water supply in short time intervals. While this delivery is fine for flooded or furrow irrigation methods for water-thirsty crops like rice, sugar cane or maize, it is less suitable for water-sensitive crops and irrigating fruit orchards and vegetables where more controlled water supply is desirable.

More innovations are therefore needed to make water delivery suitable to irrigate fruit, vegetables and other dryland crops. At the farm level, the current delivery arrangement cannot be used for drip and sprinkler systems. Future efforts are needed so that farmers can apply more flexible and controlled water distribution including the application of various forms of micro-irrigation technologies that are suitable for fruit orchards and vegetables. Bangladesh is already experiencing rapid agricultural transformation driven by economic growth and rapid urbanization. Agricultural diversification towards high-value crops is pre-eminent and future water control must be responsive to these changes.

Sustainability

The adoption of ICT for groundwater management was a response to the failure of the conventional water management practices. It has ensured the sustainability of groundwater management in several ways. First, it is easy to use and install as described in the previous section. The overall installment cost as compared to conventional water distribution is nominal. Second, it has ensured full cost recovery directly contributing to financial sustainability. Third, overall groundwater extraction has declined avoiding overexploitation of groundwater resources. The technology not only reduces groundwater mining, but also helps to address other environmental issues like salinity control and arsenic intrusion. Finally, the technology is socially accepted, easy to use and transparent. The system is therefore sustainable from economic, environmental and social perspectives.

Policy, institutional and concerned government department commitment play important roles in the sustainability of any radical reform. The ICT initiative in water management in Bangladesh has emerged out of a sound policy framework for ICT applications in the country. The BMDA is highly committed and also credited for implementation of this technology and has strengthened its institutional capacity for ICT application in water management. All these factors indicate that this initiative has already acquired institutional sustainability.

Replicability and upscaling

Rapid expansion of the prepaid meter system with smart cards in deep tubewells in Bangladesh is occurring already. The technology is compatible with local users as well as with service providers. It allows monitoring of water use at the individual farmer level and has improved overall water-use efficiency. Its application has enhanced service delivery to the farmers and increased agricultural production, while also ensuring cost recovery to the government.

All of these benefits clearly indicate that the technology is replicable and this is demonstrated by the fact that thousands of deep tubewells are already under metering systems; the same approach is now being expanded to surface water irrigation schemes involving low lift pumps. Other agencies engaged in the development and management of groundwater resource such as the Bangladesh Agriculture Development Corporation (BADC) are also adopting this technology.

As mentioned earlier, application of ICT in water management should not be seen on its own but within a context of broader economic transformation. Replicability in other parts of world including Asia would require a favourable policy environment. In addition, encouragement and assistance is required in implementing all three technology types, the hardware, software and orgware (ownership and institutional arrangement pertaining to a technology, Jespersen et al. 2014) in a mutually supportive manner, in order to ensure sustainable and effective replication. Frequently, emphasis is given only to the hardware and software components without any consideration for the orgware. One of the main reasons of the success of this ICT application has been the ownership and commitment for its adoption by the BMDA.

Conclusion

As presented in this paper, the applications of ICTs in water management are growing steadily in Bangladesh. The case study shows that ICT applications can play an important role in promoting water conservation, decreasing costs for farmers and saving power and the involvement of time and effort involved in pumping groundwater. This has a positive impact in enhancing the productivity impacts of groundwater use by improving the control that farmers have over the application of irrigation. In the long run, this could also translate into lowering the carbon footprint of agriculture. In the context of urbanization and occupational diversification, the promotion of automation can help farmers maintain a diverse livelihood portfolio.

Such initiatives have the potential to bring about larger scale savings of water. The technology can be used even with low levels of literacy among men and women. Besides, the introduction of the technology has been accompanied by the creation of a supportive workforce to operationalize it at the field level. The scaling up of the smart card system can make possible substantive savings on both power and water.

The several applications of ICTs in water management suggest that they could be a way of not only promoting livelihoods and alleviating poverty, but also be instrumental in improving governance and community engagement. The analysis also suggests that technological innovation needs to be accompanied by institutional innovation as well. Introducing new technologies needs to be accompanied by appropriate forms of institutional support.

One area where ICTs has a significant role to perform and in which their application will steadily grow in the future is in the field of climate change adaptation. The promise of enhanced participation, information accessibility and empowerment in decision-making speaks directly to the twin goals of reducing vulnerability to risk and enhancing the prospects of sustainable development (Eriksen et al. 2011; Tompkins et al. 2008).

While it is recognized that information and knowledge of climate change alone is unlikely to be sufficient to mobilize populations into action, access by diverse segments of society to appropriate and timely information has recently emerged as a core concern of climate policy. In many contexts, adaptation is understood to depend on the technical and human capacity to gather and manage the needed information flows. It is here where ICTs have an important role to play and where they can fill an important void. There are five potential functions of ICTs in the adaptation process: (1) informing decisions; b) engaging stakeholders; c) adaptation delivery; d) facilitating feedback and learning; and e) building institutional capacity. ICTs have the potential to expand access to key livelihood assets for vulnerable populations, while also contributing to broader e-resilience by providing opportunities for learning, enhanced system flexibility and cross-scale resource flows (Ospina and Heeks 2010).

There is a scant attention to ICT applications for water management in published literature. This paper has provided a basis for understanding the conditions for successful application and replication of ICT applications in water management. In related movement in India, another innovation is taking place through a separate initiative called Nano Ganesh that allows farmers to use mobile phones to remotely monitor and switch on irrigation pumps used for watering crops in remote locations. Integration of mobile phones and linking them with payment directly may further revolutionize water management in the future. Demand for water continues to rise from economic growth and environmental requirements and options to add hard water (through new infrastructure development) remain

limited (Khanal et al. 2014). Increasing soft water (saving through management options) and improving water productivity remain key options to meet growing demand where ICT applications could play a central role.

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For more information

Further information on prepaid metering systems in deep tubewells can be obtained from the BMDA, Bangladesh.

For specific information regarding this paper contact CEGIS, Dhaka, Bangladesh.

Application of the Internet of Things in Agriculture

Case study

Objective

This paper discusses Internet of Things (IoT) technology for agriculture and gives a better picture about the application of IoT applications in agricultural industry. For example, IoT technology can substitute for agricultural labour in some cases, thus alleviating problems related to workforce shortages. This smart system can be applied, *inter alia*, to irrigation, fertilization and spraying, concomitantly providing data analytics. The most significant development for traditional agriculture using IoT is risk resistance via large-scale production that it introduces.

Introduction

Context

Rural economies have attracted much attention lately. However, the ICT employed to benefit farmers is still beyond the capacity of many developing countries. IoT is a wireless sensor network-based system that aims to achieve the interoperability of various networks. In recent years, IoT has been experiencing remarkable progress and is regarded as a promising technology for driving agriculture, i.e. farming, aquaculture and the poultry industry to reduce costs and enhance rural labour use efficiency.

One of the most important applications of IoT is 'intelligent' agriculture, which places emphasis more on automation, sensors, electronic measurement algorithms, intelligent and remote wireless control of the whole production procedure instead of conventional systems that are based on labour and traditional tools.

Stakeholders and partners

Wissea Electronic and Science Co., Ltd., Yunnan Post and Telecommunications Planning and Design Institute Co., Ltd., and China Telecom (Yunnan branch) jointly conduct research and development on agricultural IoT as well as its application in the field.

Wissea is committed to providing intelligent wireless sensor network systems through product development, manufacturing and sales. The main business scope includes: wireless sensor network system platforms, wireless access equipment, IoT technology and system platforms (development and sales), wireless broadband communications technology and other electronic technology (development and sales) as well as consulting services. Wissea's technology can be used to develop smart environments, agriculture, teaching, cities, homes and other IoT domains.

The Yunnan Institute was founded in 1953 and is the wholly-owned subsidiary of China's Communication Service Co., Ltd. Its business includes: communication engineering design, communication network planning, feasibility studies and technical advice/project evaluation.

China Telecom is an information service operators, providing wireline and mobile telecommunications services, Internet access services, information services and other value-added telecommunications services primarily in China. By the end of 2015, the company had approximately 134 million wireline access lines, 113 million wireline broadband subscribers and 198 million mobile phone subscribers. The company's H-shares (shares of companies incorporated in mailand China) and American Depositary Shares (ADS) are listed on the Hong Kong and New York, stock exchanges, respectively.

Methodological approach

Requirements

The system designed by these firms includes layers of Wireless Sensor Networks (WSN), signal transmission, data processing and application as shown in Figure I1.

(1) Sensing layer

In the sensing WSN layer, all environmental parameters will be acquired in real time such as temperature, humidity, light condition, ammonia gas density via sensor measurement equipment. All these parameters and data are detected and collected by the sensor network system shown in Figure I2.

(2) Signal transmission layer

In the signal transmission layer, all parameter data are acquired, categorized and integrated as a whole package and transmitted by WSN nodes such as the Zigbee, WLAN or the mobile 3G/4G system. This paper underscores the use of wireless sensor network technology such as Zigbee and Wi-Fi and data analysis as well as processing methodology.

(3) Application layer

This achieves intelligent agricultural control through processing and analysing large amounts of acquired data and parameters submitted through the transmission layer.

The analysed data will be utilized to make decisions and initiate control measures which will be automatically realized. An example is a greenhouse in which all of the cultivation can be done more efficiently by using the IoT technology demonstrated in Figure I1.

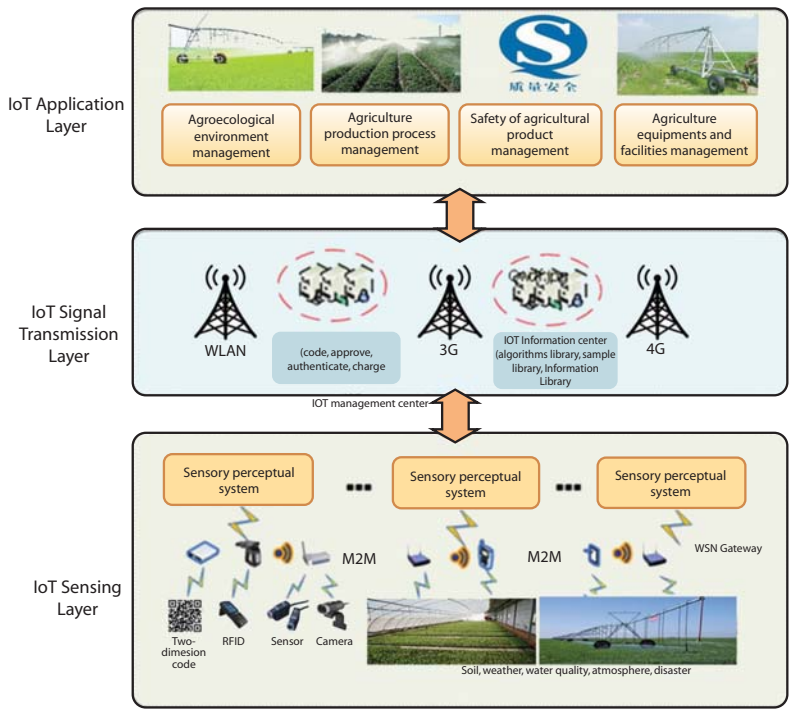

Figure I1: The structure of the rural intelligent system for the agriculture and sensor network

Wissea technologies have completed over six pilot projects in the main agricultural districts of China. It has cooperation with development partners including local governments and some listed agricultural companies such as Tangrenshen, Wenshi, etc.

Capacity development/training

The platform is treated as the brain of the IoT system. Its main function includes manipulating and managing the whole system, making regulations as well as data management and storage. It focuses on production, marketing requirements, development trends, the use of communication technology and providing clients (designers, project managers etc.) with comprehensive training.

Infrastructure

Aside from fixed and mobile communication, the IoT technology provides next-generation Internet technology such as a high-speed transmission network and IPV6. Also, China Telecom's large-scale computing system provides adaptive Internet infrastructure services for the agricultural information platform. The advanced and reliable cloud computing platform greatly reduces the investment cost of harnessing information.

Reporting

In practice, there is a need to develop standards for intelligent rural agriculture in order to drive the progress of the agriculture industry, which currently lacks the necessary regulations and standards. The company's mission is to address hunger/famine issues, assist farmers to achieve high efficiency in agricultural production and management, mitigate and control crop and animal disease outbreaks and upscal 'green' farming products. Furthermore, the company aims to make significant contributions to agricultural IoT standards and pioneer IoT in agriculture in the future.

Summary of system components/ requirements

The next generation of agricultural technology: the WSN network and data-processing system can be adapted for various wireless communication gateways, i.e. WLAN, radio frequency identity (Zigbee), 3GPP mobile communications, optimizing route and cloud computing analysis. The advanced wireless communication technologies employ WSN techniques such as Zigbee and 3G/4G mobile communication. Sensors are easy to install as they have low construction costs.

Multiple controllers: Mobile phones, PCs and tablets can be employed for surveillance and controlling procedures in real time in various farming scenarios.

Real-time surveillance and management: State-of-the-art real-time surveillance and management help users at any time to acquire information on the status of farming activities. Real-time surveillance can make the most effective decisions, reduce disaster risks and assure optimum production efficiency.

Impact

The company aims to provide further IoT applications for logistics, education, security, health care, environmental protection and transportation.

Innovations and key success factors

Environmental data acquisition system: The system has two versions – the local version which allows clients to investigate, set and control all parameters/equipment on site and the remote version which gives permission for clients to do the same thing remotely.

Automatic production system: Acquired data are processed by the professional agricultural system. These parameters are not only used for automatic production in real time and reviewed by various electronic terminals, big data processing and analysis, as well as modeling, but also allow for making decisions that can improve productivity and farming quality by optimizing crop environmental conditions significantly. In addition, the approach can help to save resources such as water and fertilizer. Another benefit clients can achieve from automatic production is agricultural security as an alarm is raised whenever any parameter exceeds the prescribed value.

Take intelligent irrigation for example. In the smart agriculture system all that is required is to set the parameters required by system. The system will do the irrigation itself by reading and analysing all data detected by the sensors. It can determine when and how much irrigation should be delivered and turn off the pump when there is enough water.

Point to multipoint wireless video monitoring system: The remote surveillance system can provide real-time information on farmland or greenhouses. All clients can acquire real-time information from either PCs or cell phones anywhere and anytime.

Agricultural product traceability system: This traces the movement of agricultural products from farm to table and monitors the agricultural products in different production chains resulting in improved quality. Consumers can easily review the whole process by scanning the electronic product code label. Therefore, customers can make the appropriate decision on which product to buy. This helps to assure food quality and safety.

Constraints

There are no perceived constraints as such except for ensuring sufficient capital for endeavours and coping with increasing demand by researchers.

Lessons learned

Good researchers with an interdisciplinary background in agriculture, telecommunications and ICT are in high demand in this field. Only those people can deliver effective products really fulfil the requirements of IoT for agriculture and thus there is a continuous search for experts with such calibre.

Sustainability

ICT, IoT, big data and cloud computing holds great promises in addressing ecofriendly, sustainable and healthy agriculture related activities.

Replicability and upscaling

Replicability and upscaling are positioned to continue as hand-held devices become more and more powerful. Also, standardized modern telecommunication technology allows the IoT for agriculture to be very flexible.

Conclusion

In future, there will be more focus on developing the IoT system for application in agricultural activities to enhance production capacity and improve product quality. We suggest further interventions via three major thrusts:

- Promotion of intelligent production in agriculture;
- Development of e-business for agricultural products; and
- Development of the product quality trace-back system.

In this paper, we have presented our various IoT applications for farming in China. However, IoT technology still has a long way to go to mature into large-scale application for agriculture.

In the Annex, we have listed a few IoT implementations.

For more information

E-mail: denise.ho@chinaccsi.com

ANNEX 1

IoT crop farming on building rooftops

Located in Kunming, Yunnan Province, the top floor of the China Telecom building has a total area of 2 000 square metres with 50 sub units for farming purposes. This system can automatically monitor different kinds of environmental parameters, which can be transmitted to the control centre through the multiple gateway for data analysis and remote control.

Multi-parameter farming environment monitor (express edition): This device can automatically collect data on temperature, air humidity and soil water content, which can be transmitted to the main computer for remote viewing.

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Farming production and traceability with IoT for the China Telecom building

Multi-parameter indoor air quality monitor

This device can monitor a variety of indoor environment parameters like total viable organic compounds (in air), temperature, humidity, CO_2, particulate matter (2.5) and noise levels. Additionally, farm clients can read these data through the mobile app and website, which allows them to know the indoor farm air quality at this farm.

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Air quality monitor

Network environment construction

The whole system transmits data through the WLAN wireless communication protocol, which accomodates a smart phone app operation platform.

All the data are managed and controlled through the smart phone app platform. Users can see their farmland information, i.e. soil water content and view live video of the farmland, as well as operate irrigation system controls.

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Smartphone Wechat app platform

Intelligent water and fertilizer synchronization irrigation system

The total farm area is about 3 600 square metres with 150 subunits. The intelligent water and fertilizer synchronization irrigation system is a combination of different IoT technologies, which include: sensors, automatic and remote control, computers, wireless communication etc. This system allows simple, automatic data collection and analysis via different wireless communication protocols, and easily allows for remote controlling, monitoring and evaluation of real and current situations at the touch of a button via PCs, smart phones and tablets.

Multiparameter farming environment monitor

This device can measure physical events such as soil water content and pH values, and allows for remote controlling, monitoring and evaluation of real and current situations at the touch of a button via PCs, smart phones and tablets.

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Multi-parameter farming environment monitor

Intelligent water and fertilizer synchronization irrigation system

This provides basic facilities and software to irrigate, fertilize and manage crops.

Independent video surveillance system

Farmers can get real-time live videos from the app and website.

Small-scale meteorological station

This device can monitor a variety of outdoor environmental parameters like air temperature and humidity, light intensity, wind direction, wind speed and precipitation. Data can be read through the mobile app and website to understand the real-time environmental situation.

Network environment construction

The whole system transmits data through the WLAN wireless communication protocol and Zigbee wireless communication protocol, which provide a low-cost, efficient, reliable transmission mode for the whole system.

Intelligent insecticidal system

This system controls the switch of an insecticidal lamp intelligently according to light intensity.

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Meteorological station, intelligent insecticidal system and intelligent water and fertilizer synchronization irrigation system (from left to right)

App and website monitoring system

All data are collected and presented through these two platforms, which also allow for other functions such as: irrigation and fertilizer synchronization, viewing live video, social media communication, ranking of users' activities, as well as storing, managing and analysing data.

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Interface of the app and the website

Intelligent agricultural greenhouse

There are four nursery greenhouses with a total area of 14 720 acres in Yunnan Province. Acquisition sensors measure humidity, light intensity, CO_2 density, soil moisture and fertility, temperature and the soil pH value, as well as provide video surveillance by remote wireless camera. The system also employs, *inter alia*, intelligent irrigation.

Multiparameter farming environment monitor

This measures physical events such as soil water content and pH value via remote monitoring and evaluation of the irrigation system at the touch of a button on PCs, smart phones, tablets etc.

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Multi-parameter farming environment monitor

Independent video surveillance system

People can obtain real-time live videos from the app and website.

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Video surveillance system

Small-scale meteorological station

This monitors a variety of outdoor environmental parameters like air temperature and humidity, light intensity, wind direction, wind speed and precipitation. These data can be viewed through mobile phone apps and the website to understand the real-time environmental situation.

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Meteorological station

Board electrical machinery control system

This manipulates switch control of ventilators, LED lighting systems and irrigation systems either automatically or manually.

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Board electrical machinery control system

Network environment construction

The system transmits data through the WLAN and Zigbee wireless communication systems, which provide low-cost, efficient, reliable transmission.

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Field installation of network construction

Monitoring centre

Various electronic terminals can be employed to provide real-time or historical data and chat feature for clients anywhere anytime. Real-time surveillance and warning information can be viewed and all equipment is operated through a remote control interface.

Monitoring centre

Farming wireless system and data-processing platform

The wireless monitoring system and data-processing platform display temperature, ventilation rate, soil water content, pH value, light intensity, wind direction, wind speed, precipitation etc. All the relevant electronic equipment can be easily monitored.

The interface of the website platform

Intelligent animal husbandry

This harnesses IoT technology to automatically record key activities such as power control, heating, ventilation system activity and environmental monitoring, i.e. temperature, humidity and ammonia content in piggeries.

Multiparameter environmental monitor

This collects, records, manages and evaluates environmental data, i.e. temperature, humidity and ammonia content and transmits these data through 3G mode to the app and website platform.

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Multi-parameter environmental monitor for intelligent animal husbandry

Independent wireless video surveillance system

Farmers can obtain real-time live videos from cellphone apps and the website.

Board electrical machinery control system

This system manipulates switch control and speed control of ventilators and curtains either automatically or manually.

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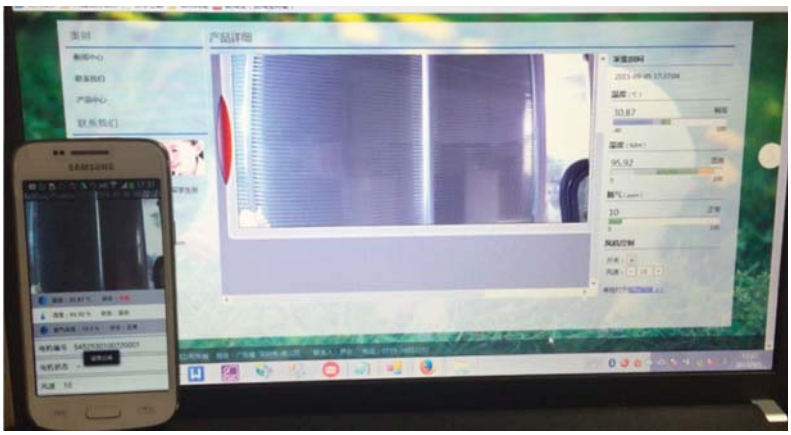
Board electrical machinery control system for intelligent animal husbandry

App and website monitor system

All the data are collected and presented through these two platforms that also allow other functions such as switch and speed control of ventilators and curtains, live inside videos of piggeries, management and analysis of data.



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The interface of the intelligent animal husbandry website

Multiparameter outdoor air quality monitor

This system has now been tested and is being used in the government institute's monitoring building. It contains more than 15 environmental parameters, which include CO_2, O_3, NO_2, PM2.5, PM10, CO, temperature, humidity, light intensity, UV intensity, wind direction, wind speed, precipitation and atmospheric pressure. Data are transmitted through wireless mode, which has low-cost installation and maintenance, as well as a short installation period. Each detector can share data within short ranges of the wireless network. Data are acquired every 1 minute and can be directly viewed and monitored using mobile phones and website. All data can be uploaded continuously through the Zigbee and mobile phone communication systems.

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The multi-parameter outdoor air quality monitor

The interface of the multi-parameters for outdoor farming air quality

ICT Application for Rural Groundwater Management in China

Case study J

Objective

The objective of this case study is to understand the use of ICT technologies for rural groundwater management in China and their impacts on the rural poor. This will help to understand the physical and policy context in which this technology is being applied and expanded, its impact on resource management and changes in water delivery services to farmers. This insight will help to improve this technology and provide data and information for its replication in other parts of Asia. It will also help to grasp ICT capabilities within water sector applications.

Geographical coverage

At present, the intelligent card (IC) card control system has been used in groundwater management for provinces where irrigation heavily depends on groundwater, such as Xinjiang, Liaoning, Shandong, Shanxi, Hebei, Inner Mongolia, Tianjin and Beijing.

Hebei is one of the seriously water-challenged provinces. This study chose four townships in Sanhe City, Hebei Province of China as research sites and conducted fieldwork in six villages employing IC cards and two villages that do not use IC cards for groundwater management.

The project villages were Dashigezhuang village of Yan Jiao township; Nanzhaogezhuang village, Xinjuntun village and Fuxinzhuang village of Yangzhuang township; Xiaocuigezhuang village of Gaolou township; and Nannie village of Qixinzhuang township. Non-project villages were Xiazhuang village and Dacaozhuang village of Yangzhuang township.

Introduction

China has scarce freshwater resources per capita. Statistics show that China's per capita water resources are only one-fourth of the world average, and the country has a global ranking of 110 in this context. China is one of the poorest countries in per capita water resources in the world (ChinaNet 2010). With the acceleration of population growth, urbanization and economic development, water shortages in China have become increasingly prominent.

Agricultural water use is facing competition from other industries and the contradiction between water supply and demand has become increasingly significant. In 2000, the share of irrigation water use accounted for 63 percent of the total water use in China, while by the end of 2013, this share had dropped to 55 percent (ChinaNet 2014).

In April 2015, steps were taken to effectively guarantee the security of food supply, the quality of agricultural products, the security of the agricultural environment in production areas in China as well as to promote the coordinated development of agriculture and rural areas. As such, the Ministry of Agriculture developed and introduced the 'Ministry of Agriculture's Implementation Opinions on Control and Prevention of Multiple Non-Point-Source-Pollution in Agriculture', which has the goal of achieving 'one control, two reductions and three basics' by 2020. The 'one control' refers to controlling total agricultural water use and the pollution of the agricultural water environment to ensure that the total amount of water used in agricultural irrigation remains 372 billion cubic metres, and water quality of agricultural irrigation water meets set standards (State Council 2015).

Facing the grim situation of overexploitation of groundwater and forming of groundwater depression cones on the North China Plain, the Communist Part of China's (CPC) Central Committee and local governments have introduced a series of policies in recent years to change this situation via promotion of agricultural water-saving technologies, agricultural water price reform, water rights trade, agricultural ecological compensation and so forth. The establishment of irrigation-measuring technology, an essential component for agricultural water price reform and water rights trade, has also been written into national and local policy reports.

The IC card measuring and control system is an advanced and important method for measuring water use. It applies computer and IC card automatic control technology in agricultural irrigation. With the IC card, individual water users can be archived and managed. Computers can be linked in the control. Each user is given a card with a user name and password written in it. When using the card, the user needs to prepay water fees to the card, swipes the card and turn on the system to retrieve water. The system automatically does the timing and charging, and deducts corresponding fees from the card. When prepayment expires, the system automatically shuts down, and retrieval of water is stopped. Introduction of the IC card technology to agricultural irrigation contributes considerably to the construction of water-conserving agriculture, enhanced water-saving awareness among farmers and the resolution of problems like unclear collection of water fees and difficulty in collecting them. It is also an important and necessary basis for the implementation of relevant policies.

The water-measuring technologies realize precise measurement of water consumption, promote households' water conservation and facilitate water price reform and water rights trade. In the 'Opinions on Promoting the Comprehensive Reform of Agricultural Water Price', the first proposal in the section of 'improving water measuring facilities' is to improve water supply measuring facilities. The 'Opinions' propose to accelerate the development of the water-measuring system. Measures proposed in it include building measuring facilities for newly-developed and reconstruction projects; rebuilding the existing projects that are not equipped with measuring facilities; equipping complete sets of facilities within a definite period in areas that are seriously short of water or have overexploited groundwater; achieving water supply via the measurement of the outlet and below in all medium and large key projects in irrigation areas; and refining units of measurement based on management requirements in small irrigation areas and end-canal systems. For sites that use groundwater for irrigation, water consumption needs to be measured by wells, and for sites with suitable conditions, water consumption needs to be measured by households (ChinaGov 2016).

In 2014, Hebei Province issued the 'Opinions on Comprehensive Reform of Agricultural Water Price in Pilot Areas Where Over-exploitation of Groundwater is Being Comprehensively Controlled', which proposed to improve measurement facilities and promote measured charges. The Opinions proposed specifically that funding is to be allocated for installing IC card measuring facilities in all water-saving projects in pilot counties to achieve precise measurement of agricultural water use and charging of water fees based on users' actual water consumption. In well irrigated areas in pilot counties, water consumption can be calculated by translating power consumption and users can be charged according to the amount of consumption. In surface water irrigated areas, water fees are charged according to the "(agricultural) outlet measurement by households and by time". For areas where the system of cumulative pricing for consumption exceeds the quota implemented, water fees should be reasonably charged with equitable and creative collecting methods (Hebei Water 2014).

Since carrying out small-scale farmland irrigation and water conservancy in key counties in 2009, Hebei Province has built over 12 000 intelligent well houses in over 30 counties (including cities or districts). The intelligent well house consists of

a protection cover, an IC card module and related facilities. It can be used alone or connected to the control centre to form an intelligent control system for irrigation (Hebei News 2013). During the 11th Five-Year Program period, Qianan City, Hebei Province invested a total of 15.71 million yuan (US$1.00 = 6.89 yuan) in building water-saving irrigation facilities for 37 km^2 of farmland, installing 307 sets of IC card facilities and laying 357 100 metres of ground-fixed pipelines. The effective irrigated area in the city reached 335 km^2 (Hebei News 2010).

Methodological approach

The IC Card Control System aims for water resource metering and water resource fee charging management, with multifunctions such as remote control, alarms, self-protection and energy-efficiency. The system is based on microcomputer technology, sensing technology and IC card technology for controlling intelligent motor pumps, maximally prolonging the service life of motors. The users can employ their prepaid cards with the IC Card Controller to start the irrigation facility when planting crops depending on their needs. The system solves many major problems that occurred in the former management of irrigation fee charges by remotely metering water and charging irrigation fees. It is also characterized by disturbance and lightning resistance and is suitable for operation in different and challenging outdoor environments.

The IC card well irrigation control system comprises the well irrigation controller, radiofrequency (RF) card (intelligent card, IC card), metering instruments (electricity meter, water meter) and water resource user management platform.

A well irrigation control box is installed beside each well and a well irrigation fee-charging management device is installed in each village (or each recharge site) to recharge the IC card for households in the local area. After installation, an IC card is issued to each household, who can recharge the card at the IC card recharging site. The user can use the IC card near the controller to start irrigation and use it near the controller again to finish irrigation and turn off the pump. Electricity (water) consumed during each irrigation event will be automatically deducted from the card and the pump will be automatically switched off once electricity (water) volume in the card runs out. Each control box can be used by several households in turn (Figure J1).

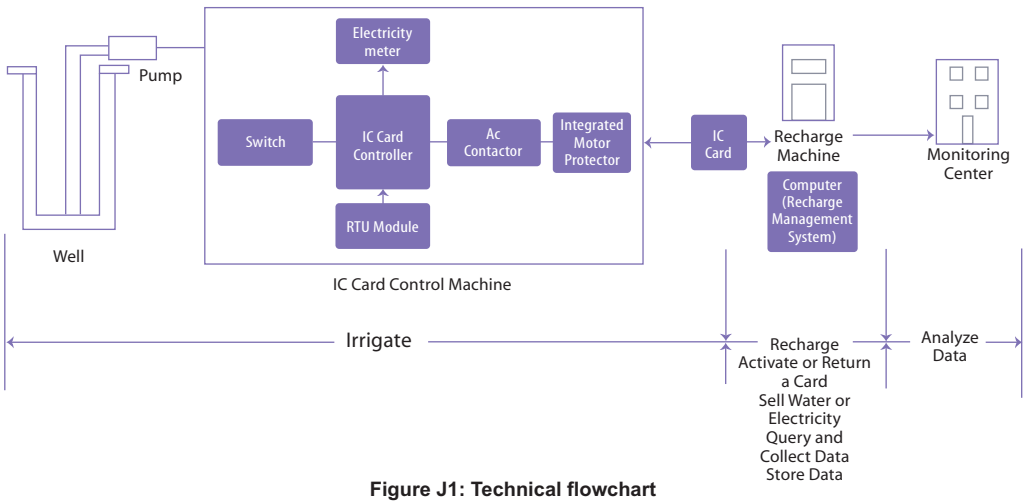

Figure J1: Technical flowchart

There are three work modes for the situation on the ground, i.e. online work mode, remote online work mode and comprehensive work mode.

Offline work mode: The RF IC-based pumped well irrigation control system in the offline work mode, using a card as the information carrier, provides a card-based prepaid management solution for agricultural irrigation.

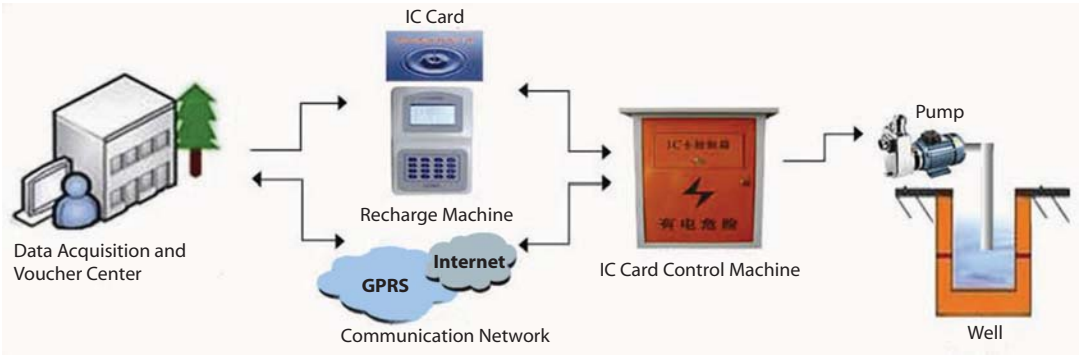

Figure J2: Offline work mode

Remote online work mode: The RF IC-based pump well irrigation control system in the remote online work mode, a card as the prepaid data carrier and General Packet Radio Service (GPRS) as the carrier for site data acquisition. It provides card-based prepaid management for agricultural irrigation as well as collection, analysis and management of well water usage information and data.

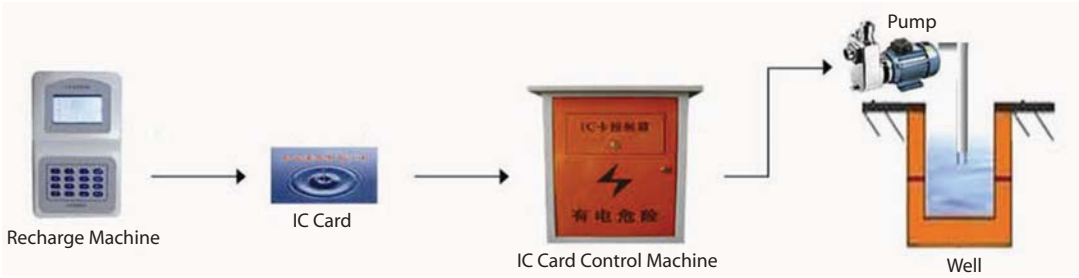

Figure J3: Remote online work mode

Comprehensive work mode: The RF IC-based pump well irrigation control system in the comprehensive work mode, a card as the prepaid carrier and GPRS as a carrier for site data acquisition. It provides card-based prepaid management for agricultural irrigation as well as collection, analysis and management of well water usage information and data, and other groundwater information and data.

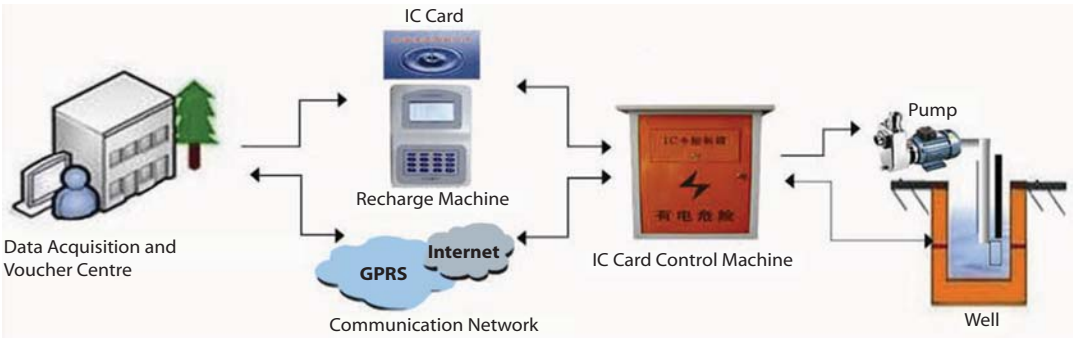

Figure J4: Comprehensive work mode

Figure J5: Outdoor Open-type and Simple Well-type IC Card Control Box

Figure J6: IC card and recharge of fees

Well irrigation control box is the key technology for IC card control system. The RF IC based pump well irrigation control box is installed with RF based pump well irrigation controller, electricity meter, ac contactor and protection device. The in-built electricity meter could be used to calculate the electricity consumed during irrigation carried out by the household (if water consumption is to be calculated, install a remote water meter at the water outlet of the pumped well). Take the product of Beijing East Victoria Times Co., Ltd. as an example. It comprises an IC card controller, electricity meter, switch, integrated motor protector, alternating current (AC) contactor and remote terminal unit (RTU) module.

IC card controller: With data-writing and storage functions, it is used for external reading under certain conditions to complete treatment and assessment of internal information. Specific functions can be divided into: monitoring of well and water consumption of each household to encourage scientific irrigation, household-rated water-use management and precharge management, household electricity precharge management, control of water pumps at the site of the water source, and remote transmission of data.

Electricity meter: To realize precise metering of household electricity consumption.

Switch: To supply power for the IC card controller or RTU module.

Integrated motor protector: To carry out comprehensive protection of the motor, mainly overcurrent protection and phase-loss protection.

AC contactor: Responsible for the on/off management of the current of the motor and starting and stopping it.

RTU module: To realize remote transmission of data and transmit the onsite data to the data centre.

Figure J7: External and Internal Look of the IC Card Intelligent Well Control BoxValidation

Random sampling surveys were carried out in sample villages using stratified random sampling. Village leaders of each village were interviewed at the village level to understand the basic situation of the village. Random sampling surveys were then conducted with approximately 20 households for each village via face-to-face interviews. A total of 115 questionnaires for project villages were distributed, and 113 valid questionnaires were collected, the effective response being 98.3 percent. Also, 51 questionnaires for non-project villages were distributed, and all of them were completed.

Impact

Cost-benefit analysis in the six project villages showed that the project is financially and economically viable using the IC card controller. Moreover, the IC card irrigation control project brings significant environmental and social benefits.

Village-level interviews revealed that there have been instances when fuses blew and circuit breakers tripped in halfway irrigation and electricians had to be called frequently for timely repair, which wasted time and caused repeated irrigation that wasted water. The village adopted flood irrigation. When the irrigation stopped because of the blowing and tripping, the water supplied leaked and the irrigation had to start again. IC card usage can save the irrigation time and improve well efficiency, favouring water conservation.

This type of irrigation is more convenient for households as they do not have to call electricians to wire well openings any more and they can now irrigate independently. Card swiping is more convenient than electric brake push-pulling. Further they do not have to queue for irrigation two days ahead as before, and can now swipe the card at any time as long as the irrigation facilities are available in the field. This saves queue time, provides greater flexibility in irrigation time, makes payment of electricity bills more convenient and reduces inconvenience from high irrigation equipment failure rates.

Water disputes have also been reduced. In the past, household electricity meters were read for electricity consumption and there would be periodic disputes relating to irrigation electricity quantity used due to inaccurate meter-recording, or incorrect charging.

Constraints

The following problems related to IC card use were raised by some households during the survey, which involved both technical deficiency and training requirements.

The design of the product led to households' improper use from the very beginning. For example, some households did not know how to use the card to irrigate and how to check data such as fees and electricity quantity balance.

The former version of the controller did not conform to the actual situation of the village. For example, electrical power required to start the IC controller did not correspond with that available in the village. This made it difficult to start the controller and the parts and accessories tended to burn out.

Computer system crash sometimes led to 'successful payment, but unsuccessful recharge'.

Besides, older electricians or accountants in some villages did not know how to use the computer to recharge and instead were more willing to use traditional approaches.

Also, unlike traditional electricity meter boxes, the IC system is a high-tech project, making it hard for electricians in the village to solve service-related problems. For example, when parts need to be replaced, there is no option but to call the company technicians who always live far from the village resulting in delays.

Former versions of the system were not of good quality and sometimes they failed to read the card or switch off. As company maintenance personnel cannot always come to the village to upgrade the system and make repairs in time, regular irrigation by villagers can be delayed.

Lessons learned

The survey revealed that the application of IC technology for rural well irrigation areas is generally successful for groundwater management.

The IC card system makes water use by households more convenient because households no longer need to record numbers on the power meter and only need to swipe the card for automatic measurement and water supply. Further, they no longer need to ask an electrician for help with wiring and opening the electrical box. There is no longer the need to queue for irrigation two or three days ahead, electricity fees can be charged ahead of time and there is no need to travel to pay fees every month.

The irrigation safety of households has been enhanced. In the past, villagers carried out farmland irrigation by using electrical switches for water supply and caused damage to the switches due to prolonged use. When it rained, they often leaked, scaring the elderly and women in the village. Swiping with the IC card has dispelled this fear and threat.

The IC card reduces water disputes and conflicts. In the past, villagers had disputes while determining their own electricity consumption. But after using IC cards and implementing the rule of one card for one household, the IC system automatically measures the remaining electricity amount and remaining amount of money that reduces conflicts and disputes arising from manual recording. In addition, households needed to make oral agreements or queue for irrigation in the past. Sometimes queue barging occurred or electrical switches were pulled when others had not finished irrigation, creating conflict. The IC card has negated these problems.

Water allocation is fairer because following the introduction of the IC card system, cases of non-payment or no recording have been reduced and so has the queuing.

Water fee collection rates have improved. Charging before irrigation with the IC card system reduces the former cases of non-payment, irregular payment and late payment of irrigation fees and has greatly enhanced the collection rate of irrigation water fees.

Maintenance frequency of irrigation equipment has been lowered. The need for minor repairs such as burned fuses has declined. Moreover, because the control box of the IC card system is equipped with comprehensive motor protection equipment, pump burn out has been reduced.

The IC card can accurately measure water consumption and effectively record the total water consumption of households, so it has become the measurement basis for water rights transactions and water price reforms.

Poor households are satisfied with the use of IC cards and think that they enhance convenience and safety of irrigation.

Sustainability

Different technical procedures in the IC card system are compatible with each other on the whole at the technical level and any incompatibilities can be easily solved technically. However, this technology is still at the embryonic development stage and needs to adapt to and coordinate with the original electricity grid and engineering systems of villages. It is estimated that a comparatively mature technical system will not be completed for another two to three years.

Some problems indicated by the households during use of the IC card are not problems of the technology itself, but of after-sale service by the

company. Some of the problems are caused by households' unfamiliarity with the new system and more training is required.

The field survey showed that farmers are generally willing to use the IC card. For example, 73.46 percent of households in the project villages are completely or relatively more willing to participate in the IC card programme. In terms of satisfaction, 79.65 percent of households gave a positive evaluation.

Conclusion

By conducting fieldwork on 164 households in six villages using the IC card for groundwater irrigation, with two villages not participating yet, the study reached following conclusions:

1. The IC card is compatible with other technical links when used for groundwater irrigation management. Most of the problems occurring in actual IC card application can be solved through technical training.
2. The application of the IC card can bring significant economic benefits, which are mainly reflected in savings on maintenance and labour costs in fee collection and reducing losses in the theft of electricity.
3. The application of the IC card can also bring significant social benefits, such as increasing the transparency of water and electricity use and significantly reducing water-use disputes.
4. All poor households that are willing to irrigate can participate in the use of the IC card without being marginalized.
5. Most of the households are satisfied with the use of the IC card, and are willing to use it.
6. In addition, the IC card has laid the foundation for water price reform and water rights trade.
7. The further benefits of water and energy savings and increased agricultural production from the application of the IC card in groundwater irrigation management remain to be seen.

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Authors

Jin Leshan, Professor, PhD, China Agricultural University, Beijing, China

Li He, PhD, Natural Resources Officer (Water Development and Conservation), FAO, Bangkok, Thailand

Li Ying, China Agricultural University, Beijing, China

Du Dan, China Agricultural University, Beijing, China

For more information

Jin Leshan, College of Humanities and Development Studies,
China Agricultural University, Beijing 100193, P.R. China.
E-mail: jinls@cau.edu.cn

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