Automating Internal Control at a Coffee Cooperative using Mobile Phones Improves Efficiency and Accountability

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ABSTRACT
Agricultural cooperatives monitor the growing practices of their members through internal control systems, ensuring adherence to external certification requirements and quality standards. In this paper, we present the motivation, design and evaluation of an automated mobile data collection, evaluation and reporting tool for internal control at a coffee cooperative. Our goals were to improve the efficiency of this process, and to increase the accountability of various stakeholders. Based on a 6-month in situ pilot evaluation, we demonstrate a 38% reduction in inspection time and 69% reduction in evaluation time, when compared to the earlier paper-based approach. These efficiency gains would reduce the cooperative's yearly expenses by $10,100, or 48% of the total internal inspection costs. Our qualitative evaluation of the system, based on focus group discussions and feedback obtained through the mobile data collection itself, documents field experiences and technical issues that arose during the deployment. The vast majority of this feedback was positive, including several comments from farmers and inspectors that the new system was more efficient and increased their accountability to the internal control process.

Author Keywords
certification, internal control, agriculture, mobile computing, data collection, efficiency.

ACM Classification Keywords
H.5.2 Information interfaces and presentation (e.g., HCI): User Interfaces.

INTRODUCTION

Challenges Faced by Small Coffee Farmers

Small farmers in the developing world must compete in an increasingly competitive economic market. Due to their small size and limited capacity, they face significant challenges in doing so. Deficits in infrastructure and organizational capacity lead to increased transaction costs when compared to larger producers. To compensate, small producers can avail a quality or marketing advantage by highlighting their specialized production techniques, geographic specialization and/or social impact. However, the lack of available transport, infrastructure, enforceable production standards and marketing channels limit this potential, causing small producers to continue to sell at commodity prices.

Coffee is a case in point. Coffee is now the second most traded commodity in the World, trailing only petroleum [3]. However, small coffee farmers, particularly in Central America, have not benefited from the increase in coffee trade and consumption. One reason is a corresponding increase in production. In the early 1990s, Vietnam started producing coffee. Coinciding with an increase in Brazilian production, the market was flooded, and worldwide coffee prices fell sharply. Growers in Central America, facing higher production costs (but growing better coffee), were decimated [6].

Certification

In response, there have been several efforts to help small coffee farmers earn a living wage by capitalizing their quality advantage, sustainable growing practices and social impact. Many of these rely on some form of *certification*, wherein a third party ensures that socially and/or environmentally beneficial practices are being followed, and authorizes producers to sell coffee with a certified label to obtain a price premium. This model assumes consumers will pay a premium for labeled products meeting specific ethical and environmental standards. Some of the more prominent certifications for coffee include:

Organic

According to the International Federation of Organic Agriculture Movements (IFOAM), organic agriculture attempts to *sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings* [7]. Actual requirements for organic produce vary from country to country. One priority is reducing the use of chemical fertilizers and pesticides. Each importing country or region usually has its own standards, enforced by a certification agency responsible for performing farm inspections to ensure quality and prevent fraud by producers. As a result, most cooperatives only export organic coffee to a few regions and/or must be certified by multiple agencies.

Shade-grown

Shade-grown certification ensures that native shade trees are retained on coffee parcels, preventing sun damage, soil ero-

sion and providing shelter to migratory birds that act as a natural insecticide [14]. Originally, all coffee was shade grown, until a sun-resistant hybrid was developed to increase the arable land available for coffee cultivation. Due to a greater yield, this hybrid has replaced 17% to 69% of the total coffee cultivation (depending on the country), severely impacting the migratory bird population. Shade-grown certification was introduced in 1996 to address this problem.

Fair Trade

Fair Trade seeks to improve the status of marginalized producers by promoting consumer awareness, changes in trading practices and empowering producers to play a larger role in the marketing and sale of their coffee [10]. Certifying agencies monitor producer organizations' labor and environmental standards. Under Fair Trade regulations, Coffee farmers are guaranteed a minimum price of $1.26 per pound, or $0.05 above the current international market price, whichever is higher. Fair Trade also encourages the establishment of direct relationships between producer organizations, roasters, and coffee importers.

Cooperatives and Internal Control

Smallholders form cooperatives to reduce transaction costs, manage quality, increase market access, engage in policy discussions and access training and technical advice. Some cooperatives also provide social services to women and other marginalized groups. Cooperatives can help smallholders achieve certified status, which can otherwise be costly and time-consuming. There is the initial challenge of training farmers in the new standards and converting their growing practices and farms (which, in the case of organic, can take up to three years). Thereafter certifying agencies conduct annual (or, in some cases, semi-yearly) external inspections, including visits to a random sample of farms. If they observe any violations of the standards, the entire cooperative's certification (and price premium) could be at stake.

A cooperative's internal control department is responsible for inspecting each member's land and equipment to ensure they meet the required standards, both for external certifications and the cooperative's own quality standards. If problems are observed, they can be corrected, or for repeated violations, the member can be sanctioned or expelled. Internal inspections are carried out by trained *inspectors*, usually staff of the cooperative or other experienced farmers (who inspect communities other than their own to avoid potential collusion).

For organic cultivation, inspectors must observe each member's processing equipment and land parcels to ensure that organic growing practices are followed and to determine whether there is a risk of contamination from neighboring fields. The results are delivered to *evaluators* who are responsible for determining appropriate recommendations and/or sanctions, which are conveyed back to farmers through *extension agents*. Inspectors must ensure that these problems have been addressed before the next inspection.

A cooperative's *internal control manager* aggregates inspection data to create a record for each farmer, and to prepare yearly reports for external certification agencies. Data can also be used for operational purposes, such as forecasting the next harvest, or to provide targeted advice and feedback to farmers. Internal control is a costly, labor-intensive process, consisting of manual data collection, entry, analysis and reporting. An overview of the process can be found in Figure 1. In many cooperatives these processes are not yet automated (or even standardized), making them error-prone and requiring significant manual effort.

Our Partner: CEPCO

The Coffee Growers Association of Oaxaca (CEPCO) is the largest cooperative of small coffee farmers in Mexico. Established in 1989 and based in Oaxaca City, CEPCO is organized into seven regional offices across the state of Oaxaca, each serving 3-10 smaller farmer organizations. CEPCO currently works with 33 such organizations, covering a total of 2760 producers, 90% of whom own less than 2 hectares of land. CEPCO's coffee is certified organic and fair trade. They employ 30 trained internal inspectors to perform yearly inspections and 17 extension agents to train farmers in organic practices. Both are recruited from the ranks of experienced coffee producers. CEPCO also has a 10-member team of evaluators. Inspectors and evaluators are hired only for the internal inspection period (usually between June and November).

DigitalICS

In this paper, we present the design, implementation and evaluation of DigitalICS — an end-to-end system for automating internal control, including mobile data collection, evaluation and reporting. Our goals were to improve the efficiency of this process, and to increase the accountability of producers and inspectors. The contributions of this paper are threefold:

- Description of the design and implementation of DigitalICS — the first end-to-end system automating internal control at agricultural cooperatives, from data collection to reporting.
- A quantitative evaluation of the efficiency gains when compared to the earlier paper-based system, based on a 6-month in situ pilot deployment — including a 38% reduction in inspection time and 69% reduction in evaluation time. By our analysis, this can reduce the cooperative's yearly expenses by $10,100, or 48% of the total internal inspection costs.
- A qualitative evaluation of the system, based on focus group discussions and feedback obtained through the mobile data collection itself, documenting field experiences and technical issues that arose during the deployment. The vast majority of this feedback was positive, including several comments from farmers and inspectors that the new system was more efficient and increased their accountability to the internal control process.

The rest of this paper is organized as follows: Section 2 discusses the evolution of internal control systems at CEPCO.

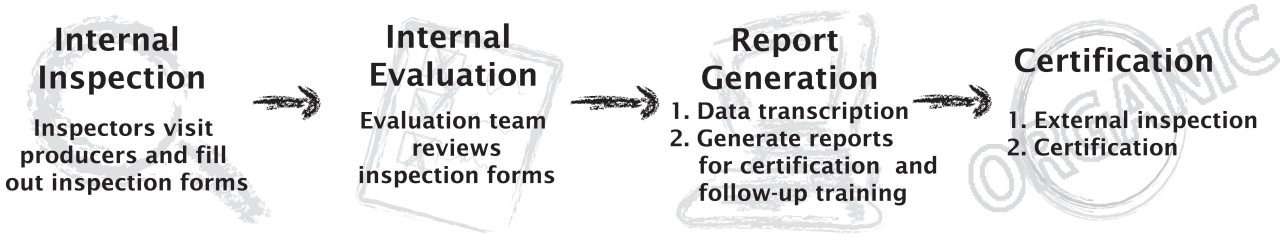

Figure 1. Flow chart of the internal control process

Section 3 describes some related (mostly commercial) systems for automating certification, monitoring, traceability and marketing of agricultural products, and prior work from the healthcare domain demonstrating the efficiency improvements that can be obtained by automating field force data collection using mobile devices. In Section 4 we present the design of DigitalICS, and the intended benefits to the cooperative. In Section 5 we describe the design and results obtained from a six-month pilot evaluation, including the observed efficiency gains, and feedback from various stakeholders documenting their experiences with and perceptions of the system. In Section 6 we present opportunities for future work, and in Section 7 we conclude.

EVOLUTION OF INTERNAL CONTROL AT CEPCO

This section provides a historical perspective on the evolution of information systems used for internal control at CEPCO.

1994-1997: 5 Page Inspection Form + WordPerfect + DBase

CEPCO's first 5-page long paper-based inspection form consisted of many open-ended questions, and required an exhaustive listing of the flora and fauna found on each parcel. The field inspections were done by the technical team at CEPCO, supplemented by a few leading producers. Evaluation was done in an ad hoc way, with each producer organization setting its own criteria. Some information, including each producer's name, estimated production, and total growing area, was entered by hand into a WordPerfect document at the CEPCO head office. Lists of organic producers were extracted and sent to certifying agencies in partial fulfillment of reporting requirements. Other reports were generated by hand. Crop estimates were stored separately in a DBase application, used by the sales department to estimate the coffee that would be available to sell.

1997-2000: 2 Page Inspection Form + Excel + DBase

In 1997, the internal control team decided to revise the process to make it more efficient and cost-effective. They reduced the inspection form to a 2-page questionnaire, with evaluation done in the field by the inspectors themselves. Inspection information was entered into Excel spreadsheets, one per organization, using pivot tables to query for information and to generate reports. Other reports continued to be generated by hand. The sales team continued to use their DBase application for forecasting purposes.

2000-2004: 3 Page Inspection + FileMaker

In the early 2000s, there was a significant increase in the number of producer organizations growing organic (from 4 organizations in 1994 to 30 in 2002). As a result, CEPCO needed a database application that would allow them to better organize, store and utilize evaluation data. They decided to use FileMaker [5], because they couldn't afford to hire a programmer, and thought that Microsoft Access was too difficult to use by non-programmers. The results of each evaluation and crop estimates for each producer were fed into this application. FileMaker allowed reports to be automatically generated — for certifying agencies, the sales team, and for funding proposals.

2004-2007: 3 Page Carbon Copy Inspection + FileMaker

Immediately prior to our arrival, inspections were conducted using a three-page paper form with an attached carbon copy — with one copy going to CEPCO, and the other to the local producer organization. Evaluators still reviewed these forms by hand, together with other supporting documents (maps, farm history, previous reports, etc.), generating one hand-written report per organization. The resulting report was entered into the FileMaker database, to generate aggregate reports for certifying agencies and other stakeholders.

Limitations of Previous Approaches

In this section, we describe some limitations of earlier approaches to internal control; based on our observations, and discussions with farmers, inspectors, evaluators and the internal control manager.

Inspection

Inspection forms consisted mostly of open-ended questions, leading to a lack of standardization and the potential for subjective bias.

Responses were hand-written, which was inefficient and difficult to do on steep coffee parcels. Inspectors had to reach a stable place before they could fill out the form, causing them to forget details.

Data was lost, either due to dirt or rain on the paper inspection forms, or illegible handwriting.

Inspectors sometimes did "office inspections", filling out reports while sitting at the office, instead of actually visiting the hard to reach coffee farms.

Evaluation

Evaluators reviewed paper-based inspection reports by hand. Each evaluation required reviewing and cross-checking up to 6 documents, again requiring significant manual effort. It took several hours to organize these documents before evaluators could begin the evaluation.

It was common to find discrepancies between documents. In such cases, evaluators consulted the internal control manager or regional offices for clarification.

Historical inspection data was difficult to access during inspection and evaluation.

Report Generation

Evaluation data was manually entered into the FileMaker database, introducing the potential for data entry errors.

Inspection forms for individual producers were never entered into the database. This again made it difficult to verify and cross-check information.

New reports were difficult to generate, especially at the producer level, because individual inspection data was not captured. This limited the use of inspection information, and required browsing thousands of paper forms to extract data for providing producer-specific feedback and advice.

RELATED WORK

We divide related work into two sections — prior attempts to automate certification and agricultural monitoring; and prior work demonstrating the efficiency improvements that can be obtained by automating field force data collection using mobile devices.

Agricultural Monitoring

e-cert is a commercial monitoring and certification system that uses a Tablet PC to perform field inspections [4]. A database application allows for the creation of inspection templates, scheduling of inspections and managing of inspection data. A group of UK food retailers developed the Social and Economic Development Exchange (Sedex), a web-based data management tool to track and audit labor standards along the wine, fruit and cut-flower supply chain [11]. ACTRES is another web-based system allowing flower growers to share information about their water and energy consumption, use of fertilizers and waste generation [9]. This is used to check compliance with certification requirements, and for growers to track their own use of natural resources. QualCheck captures quality assurance data during the processing, packaging, storage, distribution and serving of food and agricultural products [1]. Utzkapeh, an independent certifier of ethical and sustainable coffee producers, has developed a web-based system to track certified coffee through the supply chain from producers to consumers [15]. ApiTrack is a commercial product providing quality control and traceability for organic bee honey [2]. ApiTrack uses a proprietary Window CE hand held device to collect field data, indexed by barcodes printed on each apiary or beehive. Data is transferred to a web application via a wireless connection, allowing auditors to review the current status of individual beehives and/or apiaries. DigitalICS is the first system intended for automating internal control at agricultural cooperatives. It is also the first such system supporting data collection using a mobile phone, utilizing commodity hardware and open source software, potentially reducing the cost of implementing the system.

Mobile Data Collection

Many mobile phone and PDA-based systems have been implemented for field force data collection. Most relevant, Pascoe et al. designed a PDA application for mobile fieldworkers studying giraffes in Kenya. They observed that displaying prompts in sequence made the interface easier to use if the user was moving or occupied by another task [12]. However, we are aware of only one prior result — for collecting tuberculosis bacteriology data in Peru using a PDA — that empirically demonstrates the efficiency and accuracy gains that such a system can obtain [8]. This paper corroborates this result for another application domain, using mobile phone hardware, and includes an analysis of the resulting cost-savings; all of which are important areas of future work outlined in that paper.

DIGITALICS

The differences between DigitalICS and CEPCO's earlier internal control system are summarized in Figure 2. Inspection data is captured using a mobile phone, including images documenting breaches of the certification standards and the inspector's presence on the parcel; and audio recordings with feedback for the evaluation committee, the internal control manager, and/or the research team. Data is automatically transferred to a web-based application, which is used for both evaluation and report generation. The mobile phone application, the web-based application and the resulting reports are all in Spanish.

Inspection

DigitalICS includes a mobile phone application that allows internal inspectors to capture inspection data while in the field. It is written in Python for Nokia smartphones running the Symbian operating system. The application supports capturing data, audio and pictures by prompting the inspector one question at a time, both in text and audio — compensating for the small screen and making it easier for inspectors to understand. The farmer can also sometimes directly hear the audio prompt, which means the inspector doesn't need to restate the question. The survey questions are defined in a separate python module and set of audio files. This makes it easier to customize DigitalICS for new surveys and languages.

Inspectors can start new inspections or open saved ones through

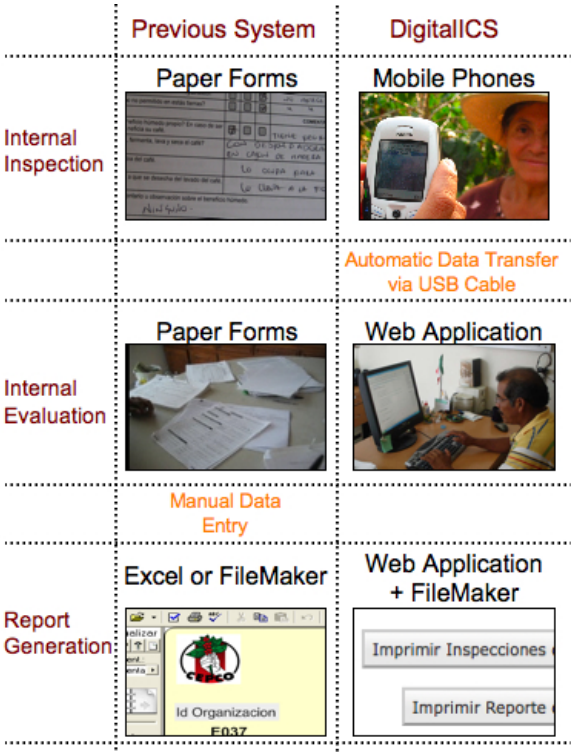

Figure 2. Flow diagram of the previous paper-based system (left) and DigitalICS (right) for the Internal Control process

the application menu. Questions can be answered in any order. The application maintains a time-stamped log of actions, to ensure sufficient time is taken by inspectors between inspections, such as walking between parcels (a safeguard against "office inspections"). The survey questions are adapted from the paper-based inspection form. This form has been modified so that most questions have either numeric, Boolean or multiple-choice answers, standardizing responses, and limiting text entry. The inspector can attach an audio comment to any question, retaining the flexibility of the open-ended format. Inspectors can also capture images to visually document breaches of the certification and quality requirements. This reduces the opportunity for producers to claim that they were treated unfairly by the inspector.

Inspectors are required to capture a picture of the producer on the coffee parcel, and of the producer signing the inspection ledger, as additional proof they actually visited the farm. They are also required to make an audio recording of the recommendations they made to the farmer, and the farmer's comments about how the community used the social premium they obtained according to Fair Trade requirements. DigitalICS also provides a feedback mechanism for producers and inspectors to send an audio message back to CEPCO (and to us) — about DigitalICS, or anything related to their relationship with CEPCO and/or the inspection process. Captured pictures, audio recordings and data can also be reviewed (see Figure 3).

Data Transfer

Figure 3. Mobile Application Screenshots: Top left: multiple options screen; Top right: recording screen; Bottom: reviewing multimedia

All captured data is saved on the phone's external memory card. After all their inspections have been completed, inspectors go back to CEPCO's head office and transfer data by removing the memory card and inserting it into a USB card reader connected to a PC. We decided to adopt a *sneakernet* solution because of the limited wireless coverage and services in the region, and to save on connectivity costs. It is not essential that inspection data be transferred to the head office immediately, and inspectors must return to the office to discuss their observations with the internal control manager anyway.

Evaluation

After data is transferred to the PC, we run a script that processes it and posts the result as a blog entry (see Figure 4). We use Wordpress as our back-end software, and Postie (a Wordpress plugin) to automatically format images and text [16]. Each post is automatically tagged with a unique code referring to each producer, providing easy access to historical data.

We have implemented a Wordpress plugin supporting evaluation and report generation. Breaches of certification standards are automatically classified according to rules specified by the management. Evaluators can log in, review inspection data (including pictures and audio), and enter their recommendations. Evaluation reports can be generated by interactively selecting data and recommendations from the inspection forms. We have also implemented a real-time, non-editable view for external certification agencies. This can eventually reduce the number of external farm visits required for maintaining certification.

Report Generation

Reports are automatically generated from the internal inspection data and evaluation results. We generate a pdf document for each farmer that includes all inspection data, follow-up comments and evaluation results; and one spreadsheet document for the entire cooperative that summarizes the inputs used, evaluation outcomes and follow-up comments. These reports are used for internal control, making supply predictions, preparing funding proposals and for reporting to third-party certifying agencies. Data is also exported to

Figure 4. Screenshot of uploaded inspection data, formatted as a blog entry.

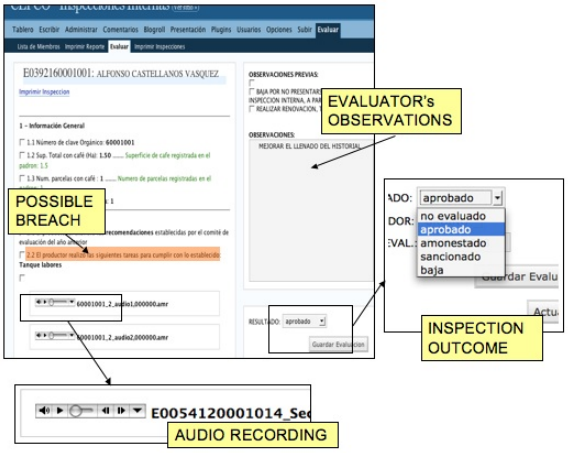

Figure 5. Screenshot of application screens used for evaluation.

the legacy FileMaker application, for generating reports that are not yet supported in the Wordpress plugin.

EVALUATION

DigitalICS underwent a successful user study in Guatemala in 2006 [13], and a small pilot test with CEPCO in 2007. Starting in June 2008, DigitalICS was used to inspect half of CEPCO's producers as part of the normal internal control cycle, while the other half used the previous paper-based system. Eight Nokia model 6600 phones were issued to CEPCO for conducting the inspections. Six inspectors were trained in the field by the first author over a two-day period. Stronger users were paired with weaker ones to help them learn the system. The Wordpress-based application for evaluation and reporting is hosted on the Internet, allowing for remote update of software and review of data by the research team. During 2008, 881 producers were inspected using DigitalICS.

In this section, we present an evaluation of this deployment, including the efficiency gains that we have documented. We also summarize field observations and other feedback gathered from inspectors, producers, evaluators and the internal control manager through various mechanisms.

Efficiency and Cost-Benefit

Methodology

To compare the efficiency of the paper-based system and DigitalICS, we collected CEPCO's accounting data for 2007 and 2008, for the twelve producer organizations using DigitalICS in 2008. CEPCO keeps detailed records of the number of producers inspected within each group, the number of days it takes to inspect them and the number of hours it takes to evaluate them. Inspectors are paid on a daily basis, while evaluators are paid on an hourly basis. Data from 2008 was compared to that from 2007, when all of these 12 organizations were still using the paper-based system.

Results

The results from this analysis can be found in Table 1. On average, it was 38% faster to perform one inspection and 69% faster to perform one evaluation using DigitalICS. When averaged across all twelve producer organizations, the reduction in evaluation time was a statistically significant difference ($p < 0.005$). Because DigitalICS greatly reduces the manual paperwork required for evaluation, including organizing and reviewing the inspection forms, and manually copying information to the evaluation reports, this drastic improvement is to be expected. In DigitalICS, all the data needed for evaluation is only entered once in the field, and is automatically transferred and consolidated for evaluation and reporting (see Figure 5). The reduction in inspection time is statistically significant as well ($p < 0.1$). However, it is not as drastic, being dominated by the time spent by inspectors walking from parcel to parcel. Considering this, even a 38% improvement is impressive.

Based on the standard wages earned by inspectors, evaluators and the internal control manager; and the reduction in inspection time, evaluation time, manual data entry, and printing costs and stationery for inspection forms; we estimate that a full deployment of DigitalICS would save CEPCO approximately $10,100 USD, or 48.3% of the total yearly cost of internal inspection. Assuming a $15,000 dollar investment in software development, purchase of 10 mobile devices at $340 USD per device, and operating costs (including web hosting, technical support and hardware maintenance) totalling $600 a year [1], DigitalICS generates a 54% annual return, with the hardware cost recouped within the first year. Future deployments will have much lower costs (considering that the DigitalICS software is open source, and that the cost of smartphones is decreasing), leading to a significantly greater return on investment.

Stakeholder Perceptions

Methodology

[1] All hardware, software and operating expenses were borne by the research team for the pilot evaluation.

Table 1. Average evaluation and inspection times based on accounting data, using the paper-based system in 2007 and DigitalICS in 2008

Description	PAPER	DIGITALICS	REDUCTION
Producers	974	881	
Inspection days	139	78	
Inspection days per producer	0.142	0.085	**37.96 %**
Evaluation hours	83	23.5	
Evaluation hours per producer	0.085	0.026	**68.69%**

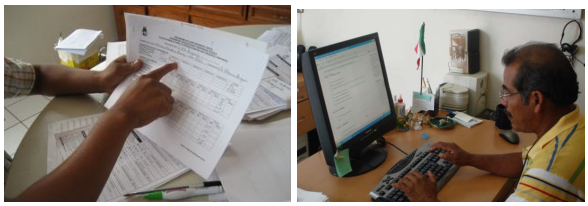

Figure 6. Conducting an evaluation with the paper-based system (left) and with DigitalICS (right)

CEPCO regularly convenes assemblies in Oaxaca City to discuss issues of common interest, including bi-monthly meetings with one representative per producer organization, as well as bi-annual meetings of all producers. The focus of the August 2008 bi-monthly assembly was "The Status of Internal Control", including deliberations between farmers, inspectors, evaluators, and management on the topic.

During this meeting we conducted the following two exercises to understand the observed benefits and drawbacks of DigitalICS when compared to the earlier paper-based approach, from the perspective of farmers, inspectors, evaluators and management. We also wanted to hear about any technical or operational issues faced by users of the system, and their real experiences when using it in the field. Both of the exercises were conducted in Spanish. Quotes have been translated by the first author, a native Spanish speaker.

Group Discussions — The participants at the assembly were divided into six stakeholder groups: four inspectors who had used DigitalICS, four producers who had been inspected using DigitalICS, two groups of producers who had **not** been inspected using DigitalICS (five and four, split because of size), four Inspectors who had **not** used DigitalICS, and one group of Evaluators (one of whom had used the system, and two who had not). Each group was asked to discuss the benefits and drawbacks of DigitalICS compared to the paper-based system. They wrote their conclusions on a big piece of paper, choosing a representative to present them to the rest of the assembly. During each presentation, the floor was open to questions, comments and suggestions from the other stakeholder groups.

Questionnaire — Four internal inspectors who had used DigitalICS completed a questionnaire covering their perceptions of the relative advantages and disadvantages of both systems, and a summary of their experiences using DigitalICS. This allowed us to learn more about specific operational issues faced while using DigitalICS in the field.

Audio Recordings — We included a feedback button in the mobile DigitalICS application to allow inspectors and producers to record audio recordings while in the field, with their questions, comments and suggestions about the system, including the option to attach an image as further documentation. This data was uploaded to the web server along with inspection data, for review by CEPCO and our research team. The goal was to allow users to comment on the system while they were in context, using the system in the field, and in a way that was non-confrontational, without the research team and/or another authority figure present. We also hoped to generate more observational data than was possible during our own limited visits to the field. Initially this was optional — inspectors accessed the feedback function if they chose to through the menu. Later we made it part of the survey, asking both the inspector and the producer to contribute one piece of feedback at the end of every inspection.

Results

During the assembly, it was difficult to keep discussions focused on the changes introduced by DigitalICS. Participants often mentioned other issues, including their frustration with the low price of coffee, the expense of certification, farmers not being notified and thefore being unprepared for the internal inspection, and other operational issues. While these are clearly important topics for the farmers and CEPCO, they are not immediately related to DigitalICS, and so we do not cover them below.

In total, there were 21 pictures and 96 audio recordings captured during the 881 inspections. Most of the pictures were irrelevant, especially when taken out of context. Sixteen of the recordings were empty or stated they had no comment. In Table 2, we provide a categorization of the most common kinds of feedback (some comments covered more than one category). It is worth noting that all producers who recorded a comment about DigitalICS had an overall positive view of the system.

This section summarizes observations from the group discussions, questionnaires and audio recordings. Observations are separated into four general categories: Inspection, Evaluation, Impact on Accountability, and Future Plans.

Inspection Inspectors that had used DigitalICS felt that the phone was lighter and easier to carry then a stack of paper forms.

Producers and inspectors that had used DigitalICS all said the system was more efficient then the earlier version.

Some inspectors liked that "the phone spoke for them", making the asking of questions easier and faster. However, some producers felt that using DigitalICS, the questions were being asked *too fast*. According to one producer,

> *There wasn't a lot of time for answering. Sometimes the phone speaks to you and then it turns off [actually, the screen saver had come on], so it didn't give us time to answer.*

Evaluators, producers and inspectors who were familiar with DigitalICS felt that inspection data was more secure from rain, dirt and/or illegible handwriting. One producer said:

> *We feel more secure because we feel the information is stored more securely (on the mobile phone)...*

One of the inspectors said that it was easier to review data using the paper-based system because "you could read the inspection report point by point". The small phone screen made such review more difficult.

Some inspectors did not like that inspection data was not conveyed to the regional office through DigitalICS. Earlier, some necessary corrections could be done there, before the inspection forms reached the CEPCO head office. Now evaluators and the internal control manager had to call the regional office for obtaining clarifications.

Inspectors who used DigitalICS liked that it made it easier to directly capture data while standing in the coffee parcel and while reviewing equipment, without requiring a stable place to sit and write.

All inspectors found it difficult to record open-ended comments using DigitalICS, and felt that important information was left out of the standardized questions and responses. Very few inspectors captured supplemental images and audio recordings. One of the inspectors said he wanted to learn how to "write" using the phone.

One inspector felt that DigitalICS was more environmentally-friendly because it could save the paper used for printing inspection forms (up to 9,000 sheets per year).

Several inspectors were worried about being held responsible for phone damage or loss. One said the phone accidentally fell into a pool of rainwater, and he was very concerned that it would stop working. All the inspectors urged us to get rain-proof covers for the cellphones. One of them half-jokingly said:

> *It would be great to build a mini phone tent to protect the mobile phone.*

All the inspectors mentioned that the phone battery discharged too quickly — usually after approximately 4-6 hours of use. Inspectors were concerned about making the arduous trek to a village without electricity, only to find they couldn't do the inspection. Most carried an extra phone or battery as a precaution.

Figure 7. Increasing accountability: The picture on the left shows an inspector taking a picture of a producer in her parcel. The picture on the right shows the inspector documenting inorganic trash (marked with a red circle).

Reviewing the captured multimedia often made the application slow down or freeze, likely due to memory and processor limitations of the phone models we were using.

Evaluation Evaluators were especially happy with the reduced paperwork and improved efficiency provided by the automated web-based application. They were especially frustrated by having to organize and sort through paper inspection reports and other related documents in the earlier system. Evaluators felt that the paper-based system led to more mistakes due to the manual work required.

Impact on Accountability Producers that were inspected using DigitalICS liked that inspectors took pictures of them and their parcels. Having pictures taken made them feel more responsible and respected for their work.

Evaluators mentioned that requiring images and audio recordings of producers increased the accountability of the inspectors (to visit the farms) and of the producers (to follow organic practices). One of them said

> *Using pictures and audio makes producers more identifiable. It is also easier to determine when the internal inspector is cheating by not visiting the coffee parcels.*

Producers and inspectors who had used DigitalICS also felt that it increased accountability. However, those that hadn't thought there could still be opportunities for cheating. One of them mentioned that an inspector could gather several producers and take pictures of all of them on the same parcel.

Another concern voiced by producers and inspectors was that DigitalICS makes it too easy to edit information on the phone, leading to opportunities for cheating. The carbon-copied paper form was thought to be more difficult to modify. One of the producers said that if you were familiar with technology, it would be easy to modify the information on the phone.

Twelve producers said in the audio recordings that the new system would make them more responsible. One said

> *Now we have to do the required agricultural activities because earlier sometimes we didn't do them but now you can see what is and isn't being done ... and that's OK because we are not playing games, we are doing a*

Table 2. Categorization of user feedback obtained through the mobile application

category	count	description
praise	36	the system is good/excellent; other forms of generic praise
efficiency	13	this system is more efficient
accountability	12	creates more responsibility for everyone to do their work
evidence	12	the phone gives more evidence of growing practices and inspection
design	11	design issues / bugs
price	9	we need a better price for coffee or more financial support
no comment	8	no comment
empty	6	empty message
agriculture	5	discussing growing practices
cooperative	3	talking about CEPCO
suggestion	3	inspector recorded recommendations for producers (which should have been recorded in an earlier question)

job to increase production and produce better coffee.

Another, referring specifically to the pictorial evidence, said

It's good because there's no deceit. Each producer needs to be responsible for [doing] their own job.

Future Plans Most of the producers, inspectors and evaluators who had used DigitalICS were ready to implement it right away across CEPCO. They encouraged training all the inspectors immediately to make sure that the system would continue to be used, even in the case of staff turnover. Other inspecctors who hadn't used the system wanted to do a more thorough evaluation to make a more informed decision based on the relative cost and benefit. It is possible that hese inspectors had seen others use the system, and simply wanted their own chance to "play".

Limitations of the Study

In this section, we list some limitations of this study:

It should be noted that CEPCO's earlier internal control system and procedures were already quite advanced, and have received significant external recognition and awards. Other cooperatives may benefit even more from the standardization and automation provided by DigitalICS; or if the basic organizational and procedural structures are not in place, may not be ready for it at all.

The cost analysis may be different for other geographies, for example in South Asia or Africa, where labor costs are much lower, reducing the financial benefit that can be obtained through efficiency gains. Transportation can also be much more difficult, making it more cost-effective to remotely transmit inspection data, especially where connectivity is widely available.

Our data is based on a sample of one cooperative's internal control for two growing seasons. A more rigorous study would involve several cooperatives, over several inspection cycles.

It is possible that the second-year results can be attributed to an "observer effect". This is somewhat mitigated by the fact that we were already working with CEPCO in 2007, using DigitalICS in parallel to the existing paper-based system. However, the possibility should not be overlooked.

As mentioned, using the previous system it was common for inspectors to do "office inspections", instead of actually visiting coffee farms. While we've made some improvements to increase accountability, it is not possible to rule out that some of the DigitalICS inspections were also not performed at the grower's coffee parcel. (We also can't know whether this is true for the paper-based system in 2007).

The format of the inspection form was changed, replacing open-ended questions with ones that could more easily be answered using a mobile device. This advantage could also carry over into the evaluation, by producing more standardized reports with well-defined rules for providing recommendations. We cannot be sure what percentage of the efficiency gains are due to this change in question format and standardization, versus the automation of the process itself.

We have not explored any of the benefits obtained by maintaining improved records of producers and their inspections. It is anticipated that these would only emerge in a longer study.

Discussion

Based on this evaluation, we have demonstrated the potential for improving the efficiency and accountability of CEPCO's internal control processes. The efficiency gains were largely found in the reduction of evaluation time, and of other overheads, including printing costs for forms. Reduction in the inspection time was not found to be as high, being dominated by the physical acts of visiting parcels and reviewing equipment. Considering this, even a 38% improvement is impressive.

During our qualitative feedback sessions, both producers and inspectors perceived an increase in their accountability to the internal control process. However, both groups also recognized that the current solution was not tamper-proof. We also describe some interesting observations from the real-world deployment, including user and stakeholder perceptions of the system, and technical issues that need to be addressed for keeping it running. Throughout the process we obtained a lot of useful feedback about the interface design and the overall functionality. We plan to integrate some of

these suggestions in the next iteration of the software. In the following section, we discuss other areas for future work.

FUTURE WORK

In this section we list some ways in which we hope to extend or refine the DigitalICS system.

The current system still cannot ensure that inspectors actually visit the coffee farms. We want to explore other guarantees, including using GPS, and other social or technical mechanisms, and measure their relative performance in ensuring compliance.

We would like to find better ways to present inspection data on the phone, including historical data, that would allow inspectors to refer to it while they are in the field. We also want to encourage inspectors and producers to capture more images and audio recordings, both as part of the inspection, and as feedback for CEPCO and the research team.

We need to investigate ways of keeping phones charged, including using solar chargers and other recharging equipment, as well reducing power consumption in our application.

We want to use the data generated by DigitalICS to improve the marketing of coffee — including making inspection data, images and audio recordings directly available on the web for consumers, and providing mechanisms to support two-way communications between producers and consumers.

Another potential use is to monitor and certify small-scale farmers receiving eco-payments for tree-growing activities. A NGO in the UK is planning to modify DigitalICS for this purpose, for use by African farmers who will thereby earn carbon credits.

We want DigitalICS to become a more general tool for cooperatives, and for any organization involved in procurement, extension, input supply, certification and more generally in maintaining relationships with farmers or other rural constituents. We have received requests for implementing DigitalICS with several other such organizations in Central America, Africa and South Asia.

While DigitalICS does save money on a yearly basis, it still requires technical support and maintenance to be sustainable. A local service provider must be willing to provide this service for a reasonable fee. The availability of open source software like DigitalICS greatly reduces the barriers for other cooperatives considering this approach. However, since we paid for the entire implementation and deployment with CEPCO, it is yet to be seen whether a cooperative would adopt such a system on their own. The first author has launched a startup to explore this possibility, and is currently in negotiation with eight cooperatives across Mexico and Guatemala. CEPCO has also bought its own phones for expanding the pilot to a full-scale deployment this year, and has agreed in principle to support the yearly support and maintenance costs.

CONCLUSIONS

In this paper we have presented the motivation, design, implementation and evaluation of DigitalICS — a mobile data collection, evaluation and reporting tool for internal control at a coffee cooperative. Based on a six-month deployment, we have demonstrated an average 38% reduction in inspection time and 69% reduction in evaluation time, when compared to the earlier paper-based approach. We have also documented the field experiences, and benefits and drawbacks, of the system from the perspective of users, farmers and other stakeholders. Based on this positive outcome, CEPCO is planning to completely transition to DigitalICS in 2009, and to use it for all of their producers during the entire internal control process.

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