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Abstract

Kheti is a mobile phone based, multimedia communication system to support sharing of agricultural knowledge and advice within a producers' co-operative. The first version of this system was designed with, and was tested by, the Sironj Crop Producers Company Ltd (SCPCL), a co-operative of small farmers working in Madhya Pradesh, Central India.
In this paper we describe the Kheti system and examine how it addresses the problems of making agricultural knowledge available by recognizing that practical knowledge is always located within a complex network of social relations and practices. We also examine the results of field trials, and some of the challenges in seeking to convert a successful technology into a sustainable development intervention.

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> *I am just like any other farmer in the village … But I was always eager to have more information on the agriculture and was a regular listener of the radio programmes such as 'Chaupal'. I found these programmes very interesting and useful because of the discussions on the agriculture issues are good and we may apply some of the methods. But this programme was not enough and I was always looking for more knowledge on innovative practices and experiments, which I could apply in my fields. I was always having a discomfort that we are not able to create any concrete 'knowledge base' for the next generation.* (Mr Ganga Ram, Chairman, Sironj Crop Producers Company Ltd., http://linux.odi.org.uk/eservblog/?p=17)

Introduction

In June 2008, United Nations (UN) Secretary General, Ban Ki Moon and the UN Food and Agriculture Organization (FAO) set a target to increase global food production by 50% by the year 2030 (Ki-Moon, 2008). One key strategy is applying information and communication technologies (ICT) to share knowledge and enable farmers to apply inputs more efficiently. A recent survey of e-agriculture, conducted by the UN's International Telecoms Union (ITU) and FAO, identified communication processes as critical, highlighting:

- "Developing virtual communities/networks for information and knowledge exchange between rural stakeholders, as well as for their empowerment through participation;
- Capacity building of rural stakeholders in use and application of ICT;
- Enhancing farmers and producers access to markets and information on farming techniques & practices
- Improving dissemination of and access to scientific and technical information;
- Enhancing access to statistics and other types of information for policy and decision-making." (International Telecoms Union, 2007).

In this paper we report on Kheti (Kheti means Agriculture in Hindi, and is an acronym for Knowledge Help Extension Technology Initiative), an ICT system to support Agricultural extension that was designed with, and tested by, the Sironj Crop Producers Company Ltd., a co-operative of marginal farmers in Madhya Pradesh, India.

Existing approaches to e-Agriculture

While agriculture remains a principal source of income in rural areas of developing countries, ICT interventions need not address agriculture alone, but can provide services that can improve rural livelihoods by increasing social and human capital (Richardson, 2006; Chapman et al., 2003). Mobile phones, for instance, are most valued for social networking, but may not be directly perceived as an instrument for economic activities (Xie & Gu, 2007). Similarly, health and educational needs are often addressed in ICT-enabled approaches. The social and human benefits of such services may lead to general livelihood benefits (Kiplang'at, 2003). In agriculture, ICT has the potential to bridge gaps in the temporal and spatial availability of extension advice, and to obviate the need to repeat established solutions to common problems for different clients (Metcalfe, 2007). Farming populations can be widely dispersed and live far from traditional information sources. Whilst having generally low levels of literacy and formal education, extension clients have specific needs according to habitat, culture, gender and production system (Fell, 2000).

ICT may also hold considerable potential for linking users with information sources and improving the timeliness and relevance of agricultural research by supporting two-way knowledge flows (Ramamritham, et al., 2005). In a gradual retreat from the modernization position, local knowledge is today becoming more highly valued, as is the need for extension service architectures to be bottom up and demand driven (Richardson, 2006). The role of the extension officer is changing towards more facilitation and local mobilization (Qamar, 2005).

Applications of ICT for agricultural extension have considered both textual and audiovisual delivery. The latter approach is surprisingly underdeveloped given the predominant oral traditions in developing countries, the ability of ICT to support asynchronous question and answer dialogues which allow responses to be reviewed and revised (Nückles, et al., 2005), and the opportunity to support consultation by reference to secondary knowledge sources (Metcalfe, 2007).

In both oral and textual cases, the technical nature of the language used by extensionists and the power relations of the actors can limit the contribution to demand driven and equitable knowledge sharing (Fell, 2000). This suggests a need for dialogue level to be tailored to participants, where additional cues and prior knowledge are important (Nückles, et al., 2005). Approaches that frame the service as a purely question/answer exchange have found that questions are typically poorly formed and defined in the first instance, and that answers are not helpful without further interpretation by an intermediary (Ramamritham, 2005). Such designs seem to have neglected the iterative nature of extension dialogue that serves to develop a common platform for understanding (Fell, 2000; Feng et al., 2006), i.e. what Clark (1996) refers to as 'Common Ground'. Other studies place more stress on the role of the "gateway manager" (for instance the manager of an electronic information kiosk) in mitigating issues of interpretation and trust (Puri & Sahay, 2007). Projects have also been challenged by issues of trust between the client and the service (Srinivasan, 2007; Veeraraghavan, 2007). These findings can be related to findings in Computer Supported Co-operative Work that highlight not only common ground, but communities of practice, social capital and human development (Carroll et al., 2006). Recent work by Patel et al. (2010) suggests some potential for audio based forum approaches in which farmers are able to hear and respond to each others' queries.

The need for extension services to be demand-driven and pluralistic has led many to champion participatory planning and implementation, thus providing stakeholders with better tailored services and with enhanced confidence to demand good service (Raabe, 2008). The active involvement of farmers in both extension and ICT-enabled services entails an understanding of knowledge and design as hands-on and necessitating the inclusion of a range of perspectives through negotiation and debate (Veeraraghavan, 2007).

Socio-technical critiques in ICT for development

In parallel with the discourse around ICT in agricultural extension, a broader debate has occurred around the role of information, knowledge and communication technology in

development contexts. Many authors highlight the importance of local knowledge and capabilities in applying ICT. Warschauer (2003) argues that effective application requires a combination of physical access; relevant content and applications; individual skills; and social or institutional resources to support usage. Van der Velden (2005) argues the importance of recognizing that much of the important knowledge for development is tacit, situated, embodied, power related and gendered. Knowledge and the people conveying knowledge, must be legitimate, trustworthy, and judged as such by beneficiaries if it is to have a positive impact on development.

Duncombe (2007) uses the livelihoods framework (DfiD, 1999) to ICT interventions, arguing that applications can focus either on directly building the assets of the poor, or on supporting the activities of structures and institutions that influence their lives (e.g. government agencies, media organisations and NGOs), organisations that Duncombe describes as infomediaries. Okon (2009) highlights the importance of integrating ICTD efforts within existing social structures and organizations, and Hussein & Tongia (2009) discuss the role of infomediaries in enabling people to convert information of different kinds into local practice. Brown (2008) draws attention to the different forms of knowledge required for local problem solving in practice, identifying: the personal felt and tacit knowledge of individuals; shared local knowledge about culture, history, and symbols; expert knowledge which may be formalized, taught in institutions and represented in texts; organizational knowledge about agendas and alliances of groups and individuals; and holistic knowledge about overall purposes and goals. She argues that approaches to community development that fail to recognize this range of knowledge types are unlikely to lead to positive, sustainable solutions.

Summary

Existing discussions of agricultural extension, and these socio-technical critiques highlight not only the importance of providing technology, relevant content and adequate financial resources, but also the significance of human, social and organizational issues. Of particular relevance are: relevant human skills in operating new technologies; local knowledge in utilizing and transforming expert input into local action; and the role of social relations and community institutions in establishing the trustworthiness of information and mediating the impact of new practices on people's livelihoods.

Project Context

Sironj is a 'block'. Local government in India is divided into states, which are then divided into districts, which are subdivided into blocks. The Sironj block is centered on the market town of Sironj and stretches for about 20 miles in each direction. The Sironj Crop Producers' Company (SCPCL) is a co-operative of small farmers from the villages around Sironj, and some farmers from the neighboring block of Lateri. At the time of this study the company had approximately 600 members. The farmers' land holdings vary considerably, but the mean holding is 3.4 bigha (1 bigha = 0.4 hectares) with the median being 2 bigha. Incomes for over 90% of these farmers are less than US $2 per day, and most combine farming with other economic activities such as laboring to sustain their livelihoods. To join the company, farmers must purchase 10 shares of 10 Indian Rupees each (i.e. 100 Rupees or approx US $2). The company's main sources of revenue are: trading members produce (e.g. Soya, wheat, gram) which it buys at a small premium over the day's price in the Sironj grain market, and sells to processors in aggregated quantities at higher prices; and trading fertilizers and pesticides which it can buy in bulk and sell to members at discounted prices. The company also has a seed breeding program to develop varieties that offer good yields, are well adapted to local conditions, but are also affordable for these farmers. The benefits of developing local seed stock are discussed by Douthwaite (2002, pp172 ff). From these operating revenues and a state government subsidy, the company pays an agricultural advisor to manage the seed program, and provide advice and support to farmers. The co-operative is governed by an elected board of directors, which includes representatives from the Madhya Pradesh State Government's 'District Poverty Initiative Programmed', and from Professional Assistance for Development Action (PRADAN), an Indian NGO with projects and initiatives in many states. Co-operatives based on a similar model are increasingly being promoted in other parts of India, taking advantage of recent changes in relevant legal frameworks (Government of India, 2002). At the start of the project, the local PRADAN team leader was also the Chief Executive Officer of the co-operative.

Kheti has been designed and developed within a project funded by the UK Engineering & Physical Sciences Research Council, which has been investigating the relation between participatory technology design techniques and participatory approaches to social development. The methods used have been reported elsewhere (Dearden & Rizvi, 2008; 2009; Dearden, Rizvi & Gupta, 2010) and have relied on extensive collaboration and

participatory working with SCPCL and its membership. Table 1 provides a timeline of the technology design and development.

May 2007	July 2007	Sept 2007	Oct 2007	Nov 29 2007	June 2008	July /Aug 2008	Aug - Nov 2008	January 2009
First contact with Sironj	Decision to focus on Sironj	Formal project startup & option appraisal	Focus set: agriculture information flow system'	First design workshop	Software complete	Selection & training of Munnas	Field trial	First draft of this paper

Design issues identified

The design of Kheti was driven by an initial joint decision to use technology to create an improved 'agricultural information flow system'. This formulation reflects an explicit 'information systems' perspective and frames the intervention as designing and implementing a new set of socio-technical arrangements within the co-operative.

In discussions and workshops with the co-operative members, directors and employees, a number of problems were identified in information flow, that are listed below.

- Responsiveness of advice from the advisor to the farmers. When a farmer needed advice, he or she would need to contact the advisor by phone (possibly borrowing a mobile phone, or using a local Public Call Office) or spend a day traveling to Sironj. The advisor would then arrange to visit, possibly after a delay of perhaps a few days. Such delays can have serious implications for crop yields, perhaps reducing a family's annual income by 10%.
- The farmers were concerned with situations where the advisor was not in the office or unavailable. The co-op did not have an answerphone, and the advisor might be away from Sironj for a number of days at a time.
- The advisor was concerned about repeating the same information or advice to many farmers. For example, how to treat a particular pest, or about the best irrigation schedule for a crop. There was a strong interest amongst the members in ensuring that the advice given led to persistent development of knowledge.
- Both members and directors wanted more regular interaction with each other.
- The advisor was concerned that he had limited information about members, particularly about land holdings and crops. This made it difficult to estimate required amounts when ordering inputs.

- The members wanted to support a process of constant learning and improvement, but the information that they held about practice from year to year was limited and anecdotal.

Kheti was designed as a socio-technical response to these issues.

Technical context

Studies of the local area in Sironj, and discussions with the SCPCL members revealed that a sizeable minority of the members owned, or had relations who owned, mobile phones. Mobile services were available to most of the villages, and many areas had GPRS data services but no one network provided complete coverage. A survey of 1200 residents, conducted at the end of the project, found that approximately 10% of residents held mobile phones, increasing to 15% for SCPCL members. Of the mobile phone holders, 70% reported that they used their phone "rarely". In comparison, 6% reported having a TV, and 2% having a radio. 66% of the respondents reported that they had electricity in their villages. Within the co-op office there was already a computer with Internet connection, and the advisor had a mobile phone. This suggested a solution combining mobile phones, the Internet and desktop computers.

A socio-technical design response

Here, we describe the technical and the social configurations that make up Kheti.

Technical configuration

The Kheti software has three major components.

The first is a mechanism for recording and logging telephone conversations between the farmers and the advisor. This is achieved by having a server attached to two telephone lines, routing advice calls through this server and using audio recording software. There are facilities to select and edit recordings and add them to a database that can be accessed by other farmers using an Interactive Voice Responder System (IVRS). Figure 1 illustrates the configuration.

FIGURE 1 ABOUT HERE

The second component is software on mobile camera phones to create 'Short Dialogue Strips' (SDS) which consist of up to 6 photographs and an audio track, similar to the

Storybank system (Jones et al., 2008). These SDS are sent to a server where the agricultural advisor can view them and respond. Typically, an SDS can be sent in under 1 minute. The advice given can be recorded and combined the questioners' audio track and added to the IVRS. The software is written in Python for Symbian 60 and runs on a Nokia Navigator 6110 which offered a fully working Hindi font. Although the users have limited literacy, they were able to use the phone's Hindi menus.

Figure 2 illustrates the configuration of Kheti for handling SDS messages. Figure 3 illustrates the use of the technology in the field.

FIGURE 2 ABOUT HERE
FIGURE 3 ABOUT HERE

The final digital element of the Kheti system is a web database of the members, their land holdings and agricultural practices (implemented using Python and mySQL). This information is useful for the advisor both in giving tailored advice and for estimating quantities when purchasing inputs such as fertilizers and pesticides.

Social configuration

These new technical systems involved new practices for both co-op members and existing staff, as well as enabling new roles within the co-op.

A central role is the 'service provider' or *Munna*[1], who held the camera phone. Each Munna took the service to a small number of villages. In the field trial each of 5 Munnas was responsible for 5 or 6 villages within a 5 km radius of their home, and was expected to visit each village at least once per week (previously, the advisor would reach each village at most once per month). 28 villages were included in the trial, and the Munnas own villages were each served by a different Munna in an effort to avoid perceptions of inequality of service. Munnas were paid a small part-time stipend, calculated with reference to the legal minimum wage. As the project evolved, the pattern adopted was that a Munna would visit two villages in one afternoon to meet with farmers and discuss issues. If problems required specialist

[1] During an early design workshop the farmers were finding it difficult to understand the task of scenario writing, which we explained by reference to the notion of 'roles' in films. The name Munna as a person who would help the farmers was inspired by the popular Hindi film character Munna Bhai

advice, the Munna would create an SDS and upload it (see Figure 2). The Munna would then return with the phone the following morning to enable the farmer and advisor to talk.
For the agricultural advisor, the new arrangements imply a new daily task of reviewing SDS, as well as additional advice conversations. It was recognized that the timeliness of response would be important in service uptake, so the project aimed for a 24 hour response. The practice that emerged was that the advisor would check his web-based inbox each evening, call the Munnas who had sent the messages, and arrange an appointment for the following day. Figure 4 shows a screenshot of the advisor's inbox screen.

FIGURE 4 ABOUT HERE

As well as the Munnas, a new role for an 'Agricultural Communication Specialist' (ACS) was created (see figure 1, bottom left). The ACS was to manage the IVRS, identifying useful advice calls and indexing them in the system, as well as collecting audio from the SDS exchanges that could be added. The ACS would install updates to the server when required, and to deal with minor software problems. The role implied good ICT knowledge, but no programming experience. Prior to the field trials the CEO and PRADAN team leader took a new post elsewhere, and the agricultural advisor was promoted to be CEO of SCPCL. It was therefore decided to recruit an ACS who could combine ICT and agricultural knowledge. The ACS would also be the line manager for the Munnas.

Field trials

The technology was rolled out for a field trial in early August 2008, which ran for 3 months. After a few system 'teething troubles', the SDSs started flowing to the Kheti website regularly from 18th August 08 onwards. Over the three months, over 200 SDS were uploaded. As a participatory action research project, the emphasis during the field trials was on supporting the SCPCL staff and training and supporting the Munnas. One of the authors (Rizvi) worked closely with SCPCL and the Munnas to assess progress, support change and discuss issues that arose. Rizvi maintained field notes and reported back fortnightly to the external project manager (Dearden). An independent project evaluation was conducted by another research unit which focused on surveying farmers in the block and examining their

socio-economic status and engagement with the project. Additionally, the authors conducted an analysis of a sample of 98 SDS which were taken and translated to English for analysis[2].

SDS contents

Of the 98 SDS messages analyzed, issues with soya (the major crop at that time of year) accounted for 28% of the total, or 38% of those messages directly associated with a particular crop. Other major crops were Chili (10% of crop specific queries), and tomato (7%). 17 different crops were discussed. The queries made were mostly regarding pests (30%), poor development of a crop (41%), or explicit suggestions and queries about disease (6%). 3 of the SDS were farmers expressing their support for and gratitude to SCPCL.

The major pests were insects (8%) including green mosquitoes (2%), or insect larvae (20%). In these cases, the images were often useful to identify the pest and suitable treatments. Figure 5 presents one example SDS, relating to a major pest threat to the areas soya crop.

FIGURE 5 ABOUT HERE.

Other SDS were requests for advice on a variety of topics including: choice of crop or seed variety for particular conditions (6%), recommended preparations and planting (3%), proper use of fertilizers or insecticides (2%), as well as administrative queries such as how to join the seed breeding program.

Over 90% of the SDS included only one or two photographs. This could indicate an interface problem, or that this domain rarely requires a large number of images. The agricultural advisor also reported that even with the photographs, it was sometimes necessary to visit personally to diagnose problems.

IVRS usage

During the trial, the IVRS received very little usage which contrasts with the findings of Patel et al. (2010). However, this may be explained by the fact that Patel et al. were targeting farmers using their own phones to access a toll-free number, whereas Kheti required the ACS and Munnas to actively promote this option to members. Given that when the Munnas and farmers were together they could talk to the advisor directly, the recorded option was

[2] Unfortunately, a proportion of the SDS were corrupted prior to the export for translation.

probably less attractive. Also, only a small proportion of SCPCL members had their own phones, so Patel et al.'s service would not reach this socio-economic group.

Local and situated knowledge

Because Kheti is firmly located within the co-op, local knowledge informs many of the exchanges. For example, in figure 6, a farmer is seeking help with a problem growing chilies. The query filename, Sonu[3], is the name of the farmer.

FIGURE 6 ABOUT HERE

Local knowledge is reflected in a number of ways here. The advisor knows the Munna by first name and recognizes the farmer's name. Further, the advisor knows (or suspects) that the farmer has not had the soil tested before planting. The advisor also knows what fertilizer mixes are available and suitable in the Sironj block (suggesting a 19:19:0 composition).
At the heart of the acceptance of Kheti and the advice given is the social relationship, and existing history of trust between SCPCL, the Munnas and the members. As Brown (2008) explains, one important element of knowledge for real life problem solving is understandings about social relations, alliances and interests. The evaluation survey found that over 80% of members trusted SCPCL more than their local council (Panchayat), block, district or state government, with 97% trusting advice from SCPCL at least as much as these other bodies.

Retaining knowledge

The role of the Munnas should not be regarded simply as mediating conversations between farmers and advisors. All of the Munnas had previously been involved as community mobilizers under other SCPCL and PRADAN initiatives, and all were engaged in some farming themselves. Hence, they were able to give advice on farming from their own learning and could direct members to sources of support for other needs. Although the Munnas did not make use of the IVRS system as a knowledge repository, they were able to build up their own awareness of knowledge that was relevant for their community. Informally, they reported that they were able to resolve about 30% of the queries they received without asking the advisor. One way to interpret this is to view the phones not as pipes carrying some fluid called 'knowledge', but to see the Munnas as actors in a network that helps the community to meet

[3] Names have been changed to respect confidentiality.

their day-to-day challenges. In terms of the livelihoods framework (DfID, 1999), the Munnas add to the capabilities of the transforming institution that is SCPCL, and increase the stock of human, physical and social capital in the villages to reduce vulnerability.

Issues and challenges

Although the field trial results were promising and there was significant enthusiasm for the system from the farmers, the system is no longer in use. The reasons for this are multiple, but highlight some important issues in researching the application of ICT for development goals.

Technical issues

Physical resources did not appear as a major problem. The quality of the mobile network improved substantially over the life of the project, and when we reached field trials, a reasonable data connection could be found in all of the villages covered. Although electricity supplies were unreliable, they were sufficient to recharge the phones when required. We discovered that our original choice of mobile phone (Nokia N73) although operating on Symbian 60 and having Hindi menus, was unable to support Hindi fonts in 3rd party software, hence we switched to the Navigator 6110.

Skills and training issues

The human skills to use the phones were adequate. The Munnas all had experience of mobile phones, and had basic Hindi literacy. However, only one of the Munnas could read English, most had no experience of SMS, and none had experience with camera phones. Even with a simple interface, using Hindi fonts and menus, there were learning issues, such as: taking good quality photographs and creating meaningful names for the SDS using the keypad. SMS is not common in India, and the keypad does not support Hindi. It took some weeks before the Munnas were confident in creating file names, and even at the end of the trial, many message names were not meaningful.

The advisor already had experience of computers for office applications, web and email, so learning the new interface was not a major problem.

The need for some technical expertise was demonstrated early on when a Munna accidentally deleted the application from one phone. Editing the IVRS required more specialist skills. However, given the low usage of IVRS, the cost of acquiring this specialist capability is hard to justify. It may be better to outsource technical support to local providers or to share the

cost of a technician between co-operatives. In the field trial, the ACS left before the end of the trial without undermining use of the SDS system.

Financial issues

For the trial, finances were all derived from external sources. The project paid for the equipment and software, covered the costs of mobile services, the office broadband service and paid the Munnas. The ACS and office electricity bills were paid by PRADAN. The advisor / CEO was paid from SCPCL trading surpluses and subsidies from state government. The primary costs of operation were: the advisor's time responding to queries; the stipends for the Munnas (1000 INR per month); the salary of the ACS (25,000 INR per month); and telephone service charges (225 INR per phone / per month[4]). The office landline can be regarded as a fixed cost, and the cost of the web server was marginal. The value of the specialist ACS is open to question, given the low usage of the IVRS system. Although some technical support is clearly necessary, this could be shared between a number of co-operatives. The primary, unavoidable operating costs are the stipends of the Munnas and the mobile services charges at 1225 INR (~ US $25) per Munna, per month. At 10 INR per query (a very high charge for SCPCL members) a service with only this income stream would require that each Munna handled 123 messages per month. However, in the trials, the number of queries generated was 15 messages per Munna, per month. Each message was costing 15 INR in network service charges, and 66 INR per message as a contribution to the Munna's stipend. Hence, the system is only financially viable if the role of Munna is integrated with other responsibilities, or if external funding could be obtained.

Two different design options can be identified.

1. The Munnas stipends would represent an extremely small part of government expenditure on agricultural extension services. The Indian state provides a social safety net in the form of an annual employment guarantee of at least 100 days of work at the minimum wage. The Munnas' work could be offered through this scheme. Many development projects by NGOs involve the work of 'local mobilization persons' to sustain links between project and community. If such a person held the phone it would substantially reduce the per message costs. Combined with a cheaper phone tariff, such a model may be more affordable for some projects.

[4] In the field trial, GPRS was only available on monthly contracts, whereas a pay-as-you-go arrangement might be cheaper for this application.

2. Alternatively, the costs of the Munnas' work could be spread if the technology were used to offer a wider range of services, such as access to health advice, e-government queries or handling data in microfinance systems. Some private sector actors might be willing to hold the phone and use it in other business activities. However, such approaches imply a very different relationship between the holder of the phone and the advice seeker, in which bonds of trust may not be as strong.

During the project, we sought to work with SCPCL and PRADAN to develop new business models to meet more of the operating costs. This was challenging, because the farmers are extremely poor. Also, it was only after many months working together that the researchers were able to obtain a detailed account of the finances of SCPCL. However, we found that, despite our repeated offers to facilitate a discussion of possible financial models, the co-op and NGO were reluctant to agree a date for a meeting.

Organizational and interpersonal issues

An issue that had to be handled with great sensitivity was the appointment of the Munnas. There were many candidates for the posts including some of the farmers who contributed to the design work. Appointment had to take into account the skills and education levels of candidates, their home locations to provide coverage, and their reputation in the community. Only a small number of positions could be funded, so some of the candidates were very disappointed. It was necessary to report the decisions with great sensitivity, and monitor the situation to avoid jealousies undermining the field trials.

Perhaps the greatest challenge was that the design created a situation where the contribution of one individual (the CEO and agricultural advisor) was critical to success. Without the advisor's continued effort responding to SDS queries, there is little incentive for the Munnas and farmers to use the system. Unfortunately, the changing priorities for the NGO (with the arrival of a new local team leader) and the demands on the CEO (such as business development; running capacity building events; the seed program; monitoring, evaluation and reporting to external stakeholders; and some incidents of violence affecting the office) meant that the commitment was not maintained after the initial field trials. Disputes arose about responsibilities and remuneration which led to unreliable services and reluctance to take over the costs of Munna salaries and airtime charges. This occurred despite earlier agreements about funding between the project and the NGO.

With the benefit of hindsight, if the research project had diverted resources from technology development to funding a longer field demonstration (e.g. by not developing all three

functions described above), and had avoided the relatively high salary costs of the ACS, the project and the NGO may have had time to secure alternative funding to sustain the Munnas' work.

This social aspect of the design demonstrates how continuous active support of local "champions" for ICTD projects is required to achieve a long term impact. In future, the authors would recommend that research projects closely examine the engagement of NGOs at all levels (not just locally), obtain written commitments from the highest possible levels, and maintain constant dialogue to ensure that design decisions reflect partners' priorities. Ultimately, we believe that sustainable innovation requires a partnership in which there is as much 'pull' from local partners looking for solutions matching their priorities, as there is 'push' from external research teams.

Summary

The experience of the Kheti design process and the field trials demonstrated the complexity of finding sustainable solutions in such low resource environments. Successful systems need to integrate technical, skill-related, social, financial and organizational arrangements. In this project, we overcame many social, skill and technical barriers, but the complex interaction of organizational, interpersonal and financial constraints proved to be more challenging.

Conclusion

Global food security in the coming decades will depend on the application of knowledge by small farmers. Agricultural knowledge needs to be ubiquitous and ready to hand for these farmers. But approaches that interpret the problem of knowledge management and communication as purely about codifying and indexing expert knowledge, or filling the 'knowledge gaps' of farmers in the developing world, are unlikely to result in real benefits for the most marginalized farmers.

Kheti approaches this problem of making knowledge usable by recognizing that practical knowledge involves a combination expert, personal and local knowledge, exercised within a set of locally controlled social structures, practices, and networks of trust. The technology was demonstrated to provide useful support to the farmers, and to strengthen communications within the co-operative. However, our experience shows that there remain many challenges in creating a sustainable socio-technical system for applying ICT in this context.

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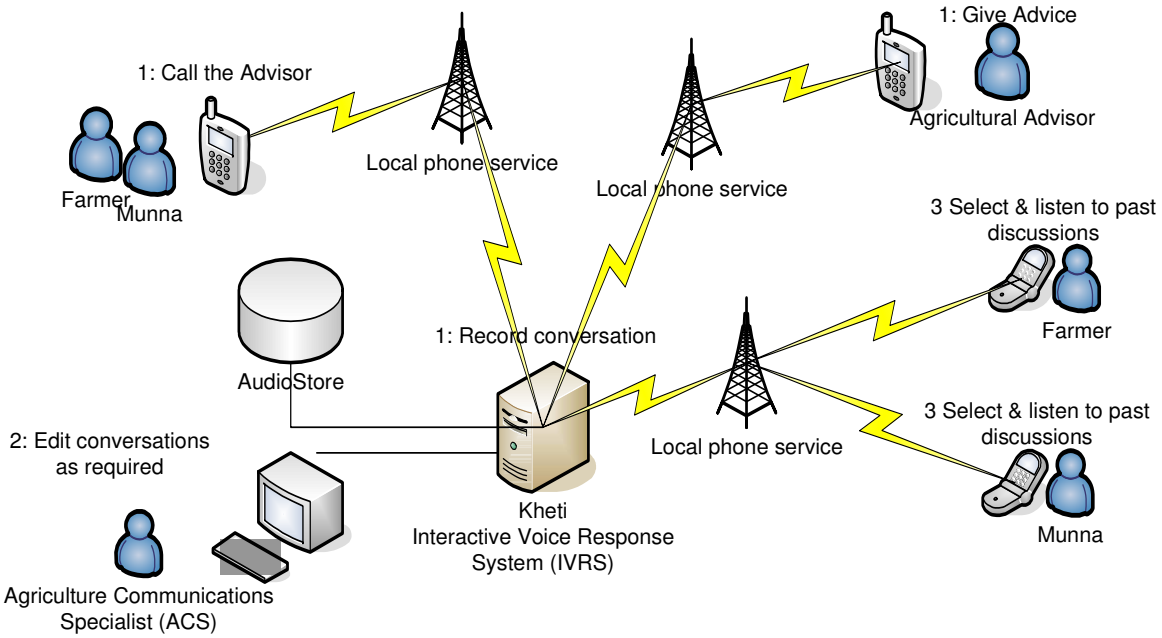

Figure 1: Using the IVRS system

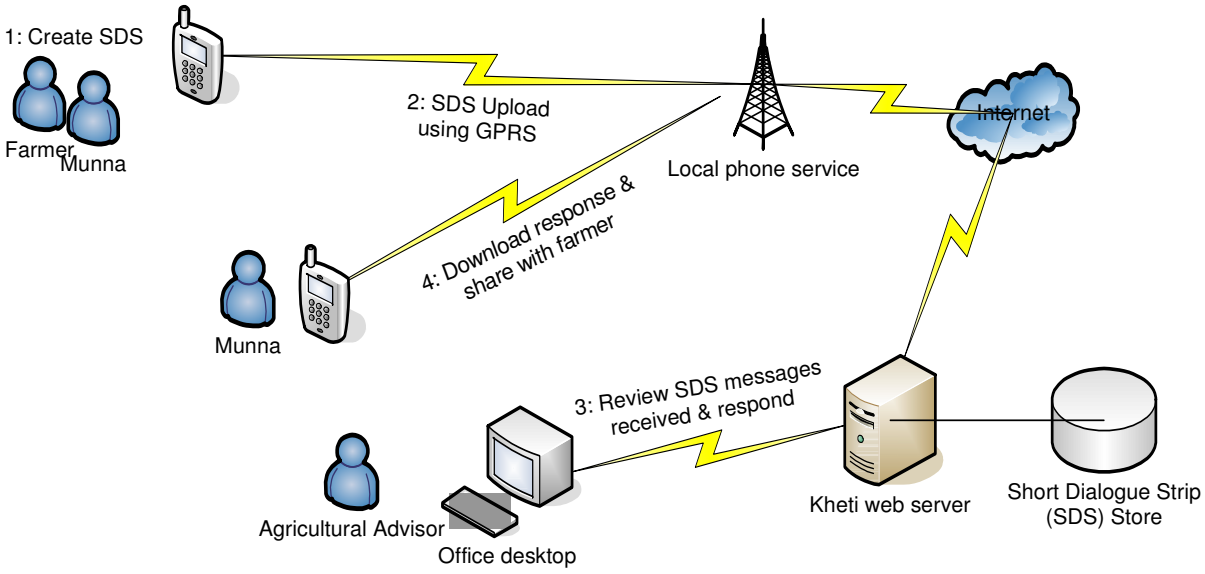

Figure 2: Using Short Dialogue Strips to seek advice.

Figure 3: Making an SDS

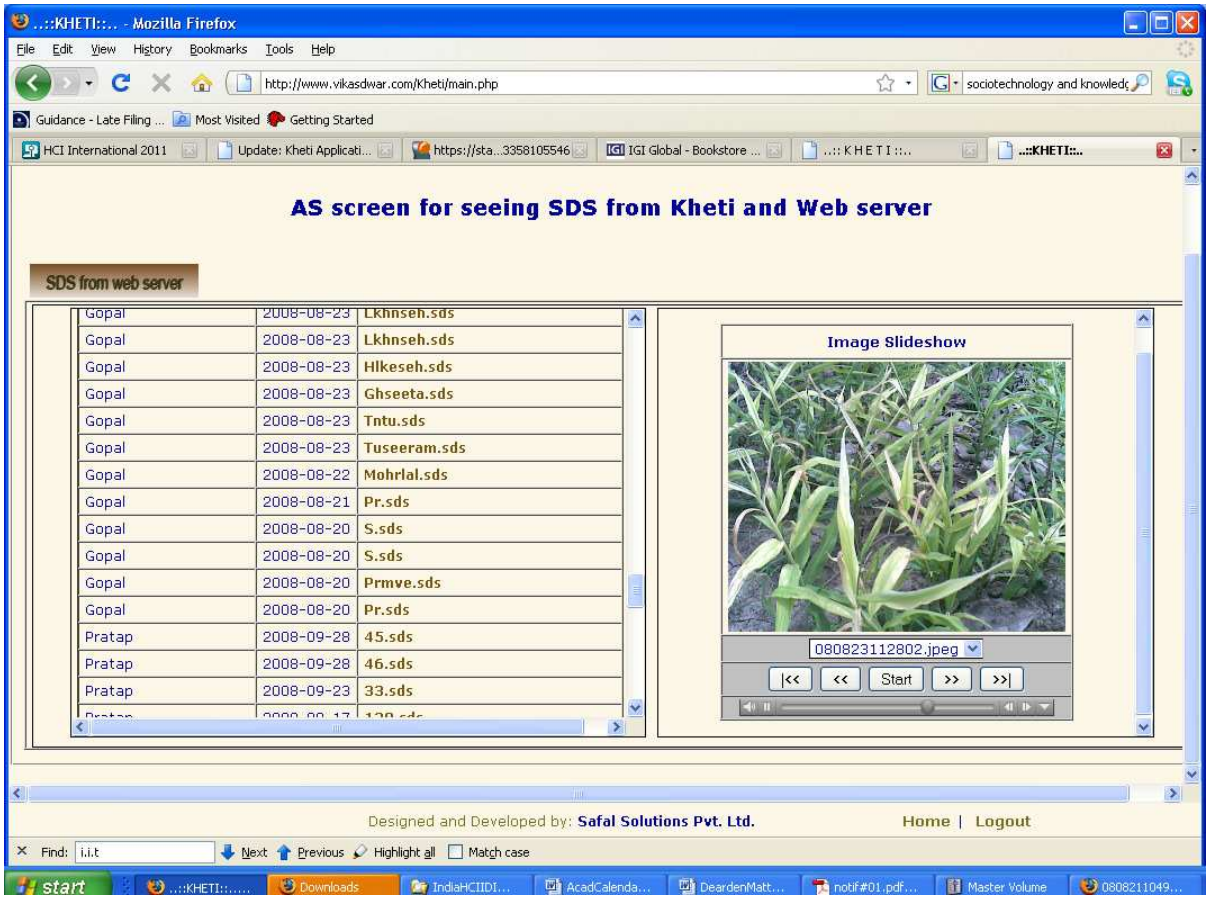

Figure 4: Advisor's web interface. The left hand part of the screen gives a list of the SDS messages received. The right hand side provides a player for the SDS.

	Munna: (Jamil) "These are chillies. These fall down from the branches before taking full shape and maturity. It is happening in 4-5 fields/plots. What is the reason for it and how it will be controlled? Please suggest."
	Advisor: "Yes Jamil, how are you. I am in receipt of your SDS which you made for Sonu. See Jamil this dropping of chillies in early maturity is due to nutrient deficiency, spray the 19:19:0 fertilizer and tell Sonu it is must to go for soil testing next year to ascertain the status of fertility."

Figure 5: An example SDS about Chillies.

	Farmer: Hello, I am Joseph from Bahadi. Suddenly there appeared an insect (*illi)* in my field. We call it *padbichchu.* What kind of insect is this? Please tell the name and the medicine to get rid of this. Also tell how to apply the medicine.
	Advisor: Yes Ramu[5], are you in Bahadi? No, no problems. Listen, the insect which has appeared in Joseph's field is the hock moth insect and it is controlled by systemic insecticide but now it is at larval stage. It is very harmful for soybean it gives large number of eggs, so we suggest the farmer to collect the larvae and sink in kerosene oil.

Figure 6: An SDS dealing with a major threat to crops.

[5] The advisor responds to the Munna. The web interface presents the