partner agents. With a direct monetary reward, experts and partner agents were more motivated to report.

Each bundle of incentives were able to generally sustain a reporting trend for on average 10 weeks. With such incentives applied periodically and interchangeably for every 10 weeks on average, it seems possible to incentivise this particular crowd for desired participation and reporting.

Discussion on challenges

During the pilot, we encountered several challenges, some technical, and some social. Many of the interventions and incentive changes during the pilot were a response to one of these challenges. For some we had no immediate solution or the solution was too expensive (in terms of resources and time) for us to implement in the pilot. The challenges generally included:

1. Most of the farmer and extension service agents were not very conversant with using mobile smartphone technologies. They largely have and use feature phones. This put a direct strain on the training budgets and most of the problems faced during the period of 76 weeks were concerned with using the mobile AdSurv app on the smartphone. However, over time the agents were able to operate some social media mobile apps, navigate the phonebook, use the camera, make calls and message with the mobile smartphone with relatively much more ease. Perhaps future research efforts may investigate a gamified crowdsourcing smartphone app, and increasing the utility features of the app to include for example commodity market information, news channels for high yielding plant materials etc.
2. When provided with weekly data facilitation, some of the agents used the data bundles for their own purposes like chatting on social media apps, and exhausted it well before being able to submit any reports. This behaviour was most dominant when weekly data facilitation was sent to them at the beginning of the week for example on Monday and Tuesday before they had to upload reports on Friday. After a follow up call and survey in the 9th week, it was noticed that most of the agents preferred submitting their weekly collections at the end of the week on days like Friday and Saturday. Starting with week 11, data facilitation was posted to the agents weekly on Fridays. This improved submissions somewhat.
3. We had many challenges related to the agents accessing mobile telephone internet with their handsets. This resulted into demotivation for some of the agents after several failed attempts at submitting reports. We got several complaints of non payments for reports which had supposedly been sent. It was unclear whether they were actually sent and lost during transmission or otherwise. From time to time, we advised the agents to collect the data and find township areas that have a good mobile internet coverage so as to send the reports uninterrupted. This however, was not as forth coming especially for agents located in rural places.
4. There was a significant problem with agents being unable to send the reports because the GPS coordinates on the app could not resolve or because they took more than 15 minutes to resolve on the phone. It was unclear whether this was due to poor connectivity or due to low quality GPS sensors in the mobile devices. Because this was a required field for the report, this quickly became a point of frustration for the agents in those areas, many times demotivating some of the agents leading to a poor and irregular performance. We made several technical visits to these places to ascertain the cause and for most cases we found the experience of getting GPS coordinates was as described (taking more than 15 min). For the most part, this was a mobile device dependent problem.
5. Some of the agents lost, broke and were robbed of their equipment which reduced the number of contributing agents from 29 to 27 agents in total. There was no way to know if the stories of lost phones were true or not.
6. Many of the agents from the rural areas and the older volunteers (above 60 years of age) were not conversant with usage of mobile smart phone technology. In the training sessions, we found that they comprehended better when guided by their fellow farmers, mostly in a local dialect. Future training will take into consideration decentralised training programs customised to the language requirements of that particular region, delivered by experienced model farmers.
7. With the increase of the direct monetary reward we experienced scenaries where an agent would report many reports from within a very small restricted locality. This was especially so with the partner agents. We observed numbers of reports for particular agents and experts shoot up from 12 to over 70 per week when the micropayment incentive was increased to 500 UGX per report. This was later countered by putting a limit on how many reports would be paid for from the same village per week. The limit was set to a maximum of 35 rewardable reports.

Recommendations from the pilot

The pilot of the mobile ad hoc surveillance system brought to light some pertinent issues in working with voluntary participants from rural areas. Some unaccounted for factors like the different levels of expertise, different literacy levels were found to affect the quality of data collected and the frequency of reporting. Some recommendations on what key factors to consider in deploying such a system include:

1. Incentives play an important role in motivating the interest of voluntary participation, even more importantly a rewards scheme through which to determine how rewards are earned. Any future research would be to understand the necessary utility considerations for designing such a rewards incentive scheme that can adaptively incentivise agents for high quality participation. 1. From the agent behaviours observed when provided facilitation type incentives e.g. mobile data credit, the time lag between issuing the incentive and broadcasting the subject for the next surveillance task should be minimised to not more than a day. This recommendation applies to crowdsourcing schemes where the duration of 1 week is still considered near real-time. 2. Under this work we register the

importance of training. For crowds that are mainly rural based, there is need for regular retraining and retooling programs. These could be a combination of online training via phone and onground live training sessions. 3. A communication strategy is key to such a framework. Particularly a strategy that emphasizes feedback to the crowd was found to be of critical importance for this type of work. 4. We found that social dynamics should be considered when implementing this type of system. We found not all participants were affected or responded the same towards certain incentives. While we did not do a rigorous study on this, we found that such dynamics as gender, age, social status, etc had a huge influence on the performance of the participants within this system.

Contributions

This work sought to find the most optimal setup possible to crowdsource all year round real-time surveillance data from volunteer agents in disparate rural agricultural localities around the country, and eventually to understand what types of incentives would be effective in motivating such a crowd. Whilst the pilot was not explicitly set up to measure the incentive mechanism, we still observe some contributions from implementing this and tweaking incentives over 76 weeks. We summarise the contributions of this work as follows.

1. We present a crowdsourcing based system to address a real world problem in Uganda. We provide the requisite evidence for using the said system to actually collect over 7000 reports from a crowd consisting of four categories of people. The contribution is in how to set up such a system as well as the experiences in getting this working.
2. We also present a live example of how manipulating different incentives can affect the outcomes of a crowdsourcing task such as this. Particularly we talk about differently motivated intrinsic and extrinsic incentives and the effect on the crowd of varying them. However working on a real problem with real people presents its unique challenges, for example having a device stolen or having the technology fail can not be solved by improving the incentive mechanism.
3. For people particularly interested in this particular problem of crowdsourcing crop health surveillance data perhaps for other crops apart from cassava, we provide an analysis of the different categories of the *crowd* and how they respond to different motivations. For example the more experienced members of the crowd respond differently to different types of incentives. Overall the social dynamics of the crowd in their localities also plays a big role, even though we were not able to demonstrate that concretely in this work.

Limitations of study

The focus of this work was to understand how agricultural actors participate in a mobile crowdsourcing setup for surveillance of cassava viral disease and pests, by drawing insights from observations on reporting patterns of individuals contributors, behaviours of their sub-groupings, their response to different incentives and the effectiveness of training exercises for rural crowds. It also looked at early benefits such a system presents in bridging the current gaps in monitoring of crop health.

While we provide insights based on 76 weeks of piloting this system, we did not set it up systematically at the onset as a controlled experiment, and as such the conclusions from this work need to be looked at in that light. However it is also important to note that it is very hard to have a controlled experiment for an actual problem like this where the actors are playing in a rural field that we have no control over. Things like stolen phones, the actors falling sick, or getting involved in other activities do affect the outputs of such a system and it would be hard to tie them to the incentive mechanism for example.

Conclusion

This work harnessed the ubiquity of farmer communities and crowds using smartphones, to provide all year-round near real-time surveillance and monitoring data of cassava viral diseases and pests in Uganda as a supplement to the standard cassava crop surveys carried out annually. We obtained 7000 reports which is about one third of the expected number of reports if the system were operating in a very controlled environment with no phones stolen, no technical difficulties, and everyone motivated to send in data over 76 weeks. The goal is to eventually use this data to build an automated diagnostic tool for cassava diseases as well as use the data to provide a real time situation map of the state of disease in the whole country. Several issues come out of this work that require further investigation for example the social dynamics of this particular crowd, how to control the quality of images uploaded in such a system and how to incentivize the different categories of the crowd. This will form the substance of our future work.

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