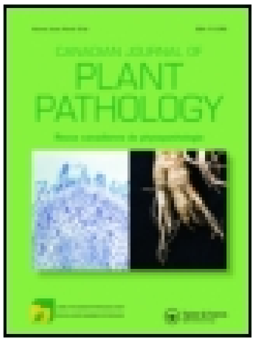


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# Building agricultural networks of farmers and scientists via mobile phones: case study of banana disease surveillance in Uganda

**GLORIA VALENTINE NAKATO[1], FENTON BEED[1,5], HEIN BOUWMEESTER[2], IDD RAMATHANI[1], SAMUEL MPIIRA[4], JEROME KUBIRIBA[4] AND SAURIN NANAVATI[3]**

[1]*International Institute of Tropical Agriculture (IITA), P.O.Box 7878, Kampala, Uganda*

[2]*International Institute of Tropical Agriculture (IITA), P.O.Box 34441, Dar es salaam, Tanzania*

[3]*Grameen Foundation, P.O. Box 35495, Kampala, Uganda*

[4]*National Agricultural Research Laboratories, P.O.Box 7065, Kampala, Uganda*

[5]*Current address: AVRDC – The World Vegetable Centre, P.O. Box 1010 (Kasetsart), Bangkok 10903, Thailand*

Correspondence to: Gloria Valentine Nakato. E-mail: V.Nakato@cgiar.org

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**Abstract:** An important challenge threatening agriculture in Africa is the difficulty to collect timely data on disease spread and effectiveness of on-farm control methods. This study served as a case study for assessing the viability of a participatory GIS (Geographic Information System) to enable plant diagnostics network with field workers. The use of mobile phone applications and a centralized database were integrated to provide a blueprint for how a range of agriculture-focused field organizations can collect data, explain events, predict outcomes, and adapt and refine strategies with more accurate, cost-efficient, and timely information. Over the course of two months, 38 Community Knowledge Workers (CKWs) using mobile phones, MTN Mobile Internet, and GPS devices collected 3,018 surveys documenting the presence/absence of three banana diseases: Banana Xanthomonas Wilt (BXW), Fusarium Wilt (FW) and Banana Bunchy Top disease (BBTD) in Bushenyi and Mbale districts in Uganda. Costs were saved by only mobilizing CKWs who then trained the communities on methods of banana disease detection, preventative measures, and disease control procedures; only when doubts over identification or control occurred did the IITA and NARO technical team then prioritize visits. Although the CKWs provided an efficient and cost effective information channel that can be leveraged to integrate the efforts of scientists with the needs of rural communities, there were significant gaps in prior farmer knowledge on the three targeted diseases, including how to identify or control them, despite extensive awareness campaigns preceding this initiative. Factsheets used for reference following training greatly improved CKW prior knowledge of disease recognition and control methods; hence, 90% of the surveys conducted during the second month met the data quality standards based on survey completeness, GPS accuracy, and quality of symptomatic plant photos. There was significant and consistent demand by farmers for CKW services throughout the pilot period. In-depth training and continuous support of CKWs is thus essential. The technology infrastructure is scalable, and further integration of technology components promises a customizable web-based tool for data collection, GIS analysis, information dissemination and management of agriculture extension operations.

**Keywords:** banana disease, community empowerment, extension, database, mobile phone, plant disease diagnosis

**Résumé :** La difficulté à collecter des données en temps voulu sur la dissémination des maladies et l'efficacité des méthodes de lutte utilisées sur les fermes constitue un des plus grands défis auquel se heurte l'agriculture en Afrique. Cette étude a servi d'étude de cas visant à évaluer la viabilité d'un système d'information géographique (SIG) participatif afin de donner accès aux ouvriers agricoles à un réseau affecté au diagnostic des plantes. Des applications pour téléphones mobiles et une base de données centralisée ont été intégrées afin d'élaborer un plan indiquant comment une gamme d'organismes agricoles à l'œuvre sur le terrain peuvent collecter des données, expliquer des événements, prédire des résultats et adapter ainsi qu'affiner les stratégies grâce à des renseignements plus précis, recueillis à peu de frais et transmis au moment opportun. Durant deux mois, 38 travailleurs communautaires du savoir (TCS) utilisant des téléphones mobiles, le service d'Internet mobile de MTN et des récepteurs GPS ont colligé les résultats de 3 018 enquêtes documentant l'incidence ou l'absence de maladies chez le bananier, dont le flétrissement bactérien du bananier (BXW), la fusariose (FW) et le sommet touffu du bananier (BBTD), dans les districts de Bushenyi et Mbale en Ouganda. Des économies ont résulté de la simple mobilisation des TCS qui, par la suite, ont formé les communautés aux méthodes de détection des maladies du bananier, aux mesures préventives et aux procédures de lutte contre les maladies. Les équipes techniques de l'Organisation nationale ougandaise de recherche agricole (NARO) et de l'Institut international d'agriculture tropicale (IITA) se sont déplacées seulement lorsque des doutes quant à l’identification ou aux méthodes de lutte subsistaient. Bien que les TCS aient constitué un canal d’information efficace et économique qui peut être renforcé par l’intégration des efforts des scientifiques aux besoins des communautés rurales, il y avait d’importantes lacunes quant aux connaissances que possédaient les agriculteurs sur les trois maladies ciblées, y compris les façons de les identifier et de les combattre, et ce, malgré les intenses campagnes de sensibilisation antérieures à cette initiative. Les fiches d’information utilisées comme référence après les séances de formation ont grandement aidé à accroître les connaissances que les TCS avaient de la reconnaissance des maladies et des méthodes de lutte. Ainsi, en se basant sur l’exhaustivité des enquêtes, la précision des mesures GPS et la qualité des photographies des plants symptomatiques, 90 % des enquêtes menées durant le deuxième mois ont respecté les normes de qualité des données. Pendant la durée du projet pilote, les agriculteurs ont constamment et en grand nombre fait appel aux services des TCS. La formation approfondie des TCS et l’appui soutenu qui leur est fourni sont par conséquent essentiels. L’infrastructure technologique est évolutive et une intégration plus poussée des composantes technologiques laisse entrevoir la création d’un outil Web adaptable pour la collecte de données, l’analyse SIG, la diffusion de l’information et la gestion des activités de vulgarisation agricole.

**Mots clés :** Maladie du bananier, autonomisation des communautés, vulgarisation, base de données, téléphone mobile, diagnostic des maladies des plantes

**Introduction**

In Uganda, banana is a fundamental crop for subsistence, source of carbohydrates, and revenue to over 70 million people (Karamura et al. 1999; FAO 2015). Unfortunately, production is limited by diseases, pests, and a range of abiotic factors (Tushemereirwe et al. 2004). Banana xanthomonas wilt (BXW) caused by *Xanthomonas campestris* pv. *musacearum* (Tushemereirwe et al. 2003) and Fusarium wilt caused by *Fusarium oxysporum* f.sp. *cubense* (Tushemereirwe et al. 2004), are among the most important diseases of banana. BXW can lead to crop loss of 100% unless management practices, such as planting clean suckers, removal of male bud (Karamura et al. 2008) and single diseased stem removal (Kubiriba & Tushemereirwe 2014) are implemented.

Fusarium wilt is capable of destroying entire plantations of susceptible introduced 'exotic' cultivars (Tushemereirwe et al. 2004) and only race 1 has been reported in Uganda (Kangire et al. 2001). *Fusarium* spores remain in the soil for over 30 years (Stover 2000); thus it is recommended to plant disease-free suckers on pathogen-free soil (Ploetz & Pegg 2000) while infested soils could be planted with the resistant East African highland cultivar (Tushemereirwe et al. 2004). Notably, both BXW and Fusarium wilt can be managed, especially if detected early. However, leaf symptoms due to both diseases are similar (Mwangi et al. 2007); therefore the need for correct diagnosis is important. Similarly, banana bunchy top disease (BBTD) caused by *Banana bunchy top virus* that is transmitted by the banana aphid *Pentalonia nigronervosa* was targeted because it is not yet present in Uganda, but there was need to pre-emptively increase awareness of the symptoms and prevent disease establishment from neighbouring DR. Congo, where BBTD was diagnosed (Kumar et al. 2011).

Agricultural extension services contextualize information to fit rural community needs (Glendenning et al. 2010), enabling farmers to benefit from agricultural research and development, resulting in testing of technology suitability to local conditions and adoption of the proven technologies (Alston 2010). Extension agents serve as feedback channels between farmers and the global agriculture community to communicate proven best practices and answer farmers' requests for more information (Aitchedji et al. 2010; Katungi & Akankwansa 2010; Kabunga et al. 2011). The concept of extension is geared towards bridging the gap between farmers and institutions generating knowledge and technologies. However, biotic and abiotic challenges have resulted in transformation of the extension system to one essentially informed by farmers' needs rather than by institution based research (Rivera et al. 2000). This has necessitated an increased interaction between farmers, extension bodies and the institutions generating knowledge and technologies.

Mobile phone technology that has rapidly been accepted in rural communities and adopted in developing countries (GSM 2008) could play an important role in fostering interaction between farmers, extension bodies, and institutions that generate knowledge and technologies. According to Aker & Mbiti (2010), 60% of the population in Sub-Saharan Africa, accounting for 376 million people, had a mobile phone connection by 2008, with Uganda recording lower mobile phone penetration compared to the rest of the countries (Gyory 2010). Currently, according to the Springs global attitudes survey, mobile phone usage in Uganda has surged from 10 % in 2002 to 65 % in 2014 (Poushter & Oates 2015). Mobile phones are considered a potential exit from poverty by the people who perceive a higher level of benefit through finding economic, social, and emergency uses of phones as the main use of phones among low income earners (de Silva et al. 2011). Several studies have validated the impact of phone usage on economic growth and development (Hardy 1980; Kathuria et al. 2009) such as easy access of information (Donner 2006; Jensen 2007;

Abraham 2007; Aker 2008; de Silva & Ratnadiwakara 2008) and improved social interactions (Bayes et al. 1999; Goodman 2005; Frost & Sullivan 2006; Kwaku Kyem & LeMaire 2006).

The popular uses of mobile phones in agricultural operations include access to the market prices of crops; timely access to solutions regarding seed-variety, fertilizer and pesticide availability/application, and calling distant agriculture specialists for technical advice (Martin & Abbott 2010; Aker 2011; Mesiku 2011). Significant savings in both time and money have been reported by farmers by of reducing unnecessary travel and time-related expenses, increasing bargaining power through access to market information, and increasing yields or reducing losses through access to remote technical advice (Jensen 2007; Martin & Abbott 2010). Research also provides evidence on the key role that mobile phones are playing in serving farmers' need for information (Campaigne et al. 2006). For example, Martin & Abbott (2010) reported that 82 % of survey respondents used mobile phones for farmer mobilization, meeting and training coordination, and for obtaining 'agricultural inputs' from suppliers, agriculture -based organizations, and local farmers.

Poor information flow limits productivity and revenue of smallholder farmers, resulting in market inefficiencies. Currently, smallholder farmer activities in developing countries are monitored by government-sponsored agriculture extension agencies or unregulated non-government organisations that occasionally provide information collected in an expensive, time consuming, and uncoordinated manner. Collecting information associated with specific farm location is part of the solution in assisting farmers with decision making to increase crop management and cost-effectiveness. The Grameen foundation (www.grameenfoundation.org) through the Community Knowledge Worker (CKW) initiative specifically targeted smallholder farmers to try and fill a critical gap through improving information flows and linking players along the value chain. Community Knowledge

Workers are local leaders who actively disseminate and collect information in their communities. The CKWs were nominated from a variety of organizations working with farmer communities and trained in data collection and information delivery techniques using mobile phone applications, such as conducting digital surveys, delivering weather, market, and agriculture information obtained through SMS, and providing farmers with direct access to agricultural information through an agriculture call centre. International Institute of Tropical Agriculture (IITA) and National Agriculture Research Organization (NARO) provided scientific expertise and technical backstopping. This study aimed at building a network of stakeholders managing banana diseases as well as establishing the fundamental role of mobile phones in agricultural extension using identification, mapping, monitoring, and controlling banana diseases as case studies in Uganda.

## Methodology

### *Target area*

The pilot study was conducted in Bushenyi and Mbale districts in Uganda, both important banana-producing districts located in western and eastern Uganda, respectively. CKWs were selected on geographic grounds, forming a network that covered potential hot spots of banana disease. The CKWs targeted smallholder farmers with farmland less than 2 hectares, located not further than 5 km radius from their homes.

### *Survey questionnaire*

Each CKW was given a mobile phone on which an application was installed that consisted of a survey with 50 open-ended and multiple-choice questions. The questions related to disease incidence, crop management practices, availability of agriculture information, importance of banana to food security, income, and knowledge of banana disease control practices. The application recorded the coordinates where each survey was completed and allowed a CKW to upload pictures (e.g. of disease symptoms). Each mobile phone was GPRS enabled and designed to permit remote download of the survey forms.

*CKW preparation*

The CKWs were nominated from various organisations working with farmer communities in the two districts (Table 1); and trained on agriculture extension techniques targeting banana disease information and dissemination, data collection, and use of mobile technologies for data collection. CKWs that accurately and correctly obtained farmer information during the test of concept exercise were selected to form the two CKW networks, one in each of the two major banana-producing districts of Bushenyi and Mbale in Uganda. Each CKW was provided with a reference guide, and factsheets. The guide and factsheet included instructions on how questions should be asked, how farmers' responses could be verified, how phones should be used, how surveys should be conducted, and how banana diseases should be identified and managed. The CKWs were trained on how to take photos of diseased plants using their phones to substantiate diagnosis on the submitted questionnaire.

The recorded data were wirelessly transferred straight from the field and stored in a centralized database. In the first month, all CKWs recorded the survey data digitally on their phones and on traditional paper questionnaire forms. In the second month, only digital surveys were recorded.

*Data accuracy*

Data verification visits were conducted on selected farmers to confirm the accuracy of the surveys submitted by the CKWs, to verify areas of high disease incidence, to determine if the surveyed farmers implemented the appropriate control measures, and to investigate the farm by sampling infected plants to determine the extent of disease on the farm. Four percent

(4%) of the surveys submitted by each CKW were monitored and evaluated for correctness in survey administration. The farms selected included those reported to have BXW and Fusarium wilt incidences of 100% per farm as well as those reported to have BBTD symptomatic plants. At least five plants from the selected farms were returned to the IITA pathology laboratory for precise diagnosis of the causal agent responsible for observed symptoms using polymerase chain reaction (PCR) (Mansoor et al. 2005; Lewis Ivey et al. 2010).

*Database analysis*

Global Positioning System (GPS) data was used to generate maps using ArcGIS software that showed the exact location of farms surveyed by each CKW. Data were analyzed using ANOVA and means separated with least significant difference at 5% using the GenStat 12th Edition statistical software (VSN International Ltd 2009).

## Results

In two months, 3,018 farm surveys linked to GPS coordinates were recorded by 38 CKWs in Bushenyi (Fig. 1A) and Mbale (Fig. 1B). A total of 1,702 digital surveys were submitted in the first month and 1,316 digital surveys in the second month for both Bushenyi and Mbale. On average, each CKW completed about nine surveys per week at an average cost of 3,500 Ugandan shillings per day; nearly a tenth the cost of similar activities administered through government sponsored agriculture extension officers (Kibwika & Semana 1998; AfranaaKwapon & Nkonya 2015). For each submitted survey, the CKW was compensated 3,500 Ugandan shillings, based on completeness, that is, all survey questions answered, correct GPS coordinates recorded and the picture correctly attached to the mobile survey.

*Paper versus digital*

In total, 812 & 942 paper surveys and 856 & 846 digital surveys were submitted from Bushenyi and Mbale, respectively. The number of paper surveys did not equal the number of digital surveys; 10% of the paper surveys were disregarded due to error in recording coordinates, or were torn and information missing. The accuracy of the digital surveys was assessed by comparing with the paper surveys. Furthermore, several paper surveys were torn, illegible or lost. On average, digital surveys took less time (about 30 min) than paper surveys (about 60 min) to complete.

*Disease incidence*

BXW and Fusarium wilt were present in both Bushenyi and Mbale (Table 2). Significant differences ($P<0.05$) were observed in BXW incidence, with 75% of the surveyed farms in Bushenyi having plants with characteristic BXW symptoms compared to only 69 % farms in Mbale (Table 2). No significant difference in Fusarium wilt incidence for both districts was found. No BBTD was observed in either district.

*Farmer awareness of banana diseases*

Significant differences ($P<0.05$) were observed in farmer awareness of the three target diseases in both districts (Table 3). Most farmers could describe symptoms and methods of managing BXW. However, farmers' awareness on Fusarium wilt symptoms and methods of managing it were remarkably low, despite its long presence and severe impact. Less than 5% of the farmers in both Bushenyi and Mbale were knowledgeable of BBTD. Farmers in Bushenyi were more knowledgeable on the banana disease management practices than in Mbale. In total, 75 % and 35% of farmers in Bushenyi compared to 42% and 15% in Mbale knew how to manage BXW and Fusarium wilt, respectively. Control of BBTD was the least known in both districts.

*Data accuracy*

In total, 127 farmer fields (4% of surveyed farms) were revisited. On all revisited farms, the CKWs accurately identified and estimated the incidence levels of BXW but not Fusarium wilt (Fig. 2). Although BBTD was reported in both districts, no symptomatic plants were observed on the revisited farms but also, it has never been confirmed in Uganda. All the 127 farmer fields that were revisited had cut down BXW symptomatic plants and the farmers confirmed that they disinfected their tools by flaming rather than using jik (a disinfectant) that was expensive to buy.

*Phone use for agricultural activities*

In total, 22% of farmers in Bushenyi and 28% in Mbale confirmed that they use their mobile phones to obtain agricultural information on management practices to increase yields, control diseases, and on what input supplies to use. Of the farmers who used mobile phones, 58 and 53% in Bushenyi and Mbale, respectively, used their phones to obtain information on how to manage diseases, 21% to obtain information on input supplies and 5 and 15%, in Bushenyi and Mbale, respectively, on crop management practices to increase yields (Fig. 3). Only a few farmers used their phones to inquire about market prices or to identify selling opportunities.

## Discussion

This study shows that farmers surveyed in two districts in Uganda provided CKWs with a wealth of information that was transmitted via mobile phones directly from the farm to a centralized database. The benefit of this approach is that extension was not top down but participatory, linking farmers and scientists who could ask each other questions and give answers. A lot of research stresses the benefits of involving the farmer in research and the extension process as opposed to the top-down approach where the extension system disseminates proven findings to them (Hall & Clark 1995; Agbam 2000; Ton 2005).

More than 3,000 farmers were surveyed in this study. This large number was mainly possible because the CKWs were not restricted to locations but could gather information wherever they travelled. In the first month, paper surveys were collected that served as backup and reference to the digital surveys. Research by Aker (2011) suggests mobile phones have colossal potential as conduits of conveying extension services to marginalised farmers and thus permit overcoming challenges of the traditional extension system. We agree with Aker's findings and would like to add that when comparing digital to paper surveys: 1) Digital surveys save time by ensuring ease of movement by CKWs in the field which is not restricted by bulkiness of paper surveys, and by avoiding clerks entering the data (about 15,000 pages of paper questionnaires was collected in the first month alone). In addition, the digital surveys were more accurate and eliminated errors, especially for coordinates of surveyed farms. 2) The paper questionnaires were more expensive as a result of printing and transportation costs, difficult to distribute to remotely located CKWs, and obviously could not include digital photos. The paper questionnaires assisted CKWs in getting to know the survey format for easy transfer of data into the mobile application.

These results will help to identify and prioritize appropriate agriculture extension activities and the technical requirements needed to monitor the spread of the targeted banana diseases. Subsequent action could include harmonizing disease identification, disease prevention and best management practices of diseases with the national programs; and developing radio campaigns for the wider distribution of information on banana disease management (Karamura et al. 2006; Blomme et al. 2014). Radio campaigns are used as tools to influence public opinion and policy makers since they reach a wider audience and are accessible to people who are otherwise isolated by geography, illiteracy and poverty. They play a significant role in spreading information and raising awareness, thus influencing and changing public opinion and behaviour; leading to public pressure on local policy decision makers.

It is important to use the appropriate diagnostic methods to diagnose and detect pathogens in order to ensure effective surveys (Petter et al. 2008; Ramathani & Beed 2013). Incorrect reports from extension agents calls for the need for technical backstopping (Smith et al. 2008; Waage et al. 2009) in order to direct finances towards the appropriate management interventions. There is need to equip extension workers and CKWs with tools that allow identification of disease in the field and to ease sample collection for diagnosis in the lab (Ramathani & Beed 2013). For example, the incidence of BXW was sometimes incorrectly estimated because CKWs were relying on farmer estimations of presence of disease without actually verifying this number by cross sectional analysis of the farmer's field.

Farmers in Bushenyi were more knowledgeable on the biotic constraints of banana as well as their management options. Adoption of BXW management options has depended on geographical regions (Tushemereirwe et al. 2006), farm size (Blomme et al. 2014), and degree of stakeholder mobilization (Kubiriba et al. 2012). In both districts, there were fewer reports of Fusarium wilt compared to BXW; this is likely due to the fact that many of the farmers have the East African Highland banana cultivars that are known to resist Fusarium wilt infection (Tushemereirwe et al. 2004). However, the close similarity between symptoms due to BXW and Fusarium wilt could explain the incorrect reporting of Fusarium wilt incidences (Mwangi et al. 2007).

Overall, results from the revisited farms indicate a degree of accuracy in estimating the presence and incidences of BXW and Fusarium wilt, especially where the plants had full blown symptoms of both diseases. In order to distinguish between BXW and Fusarium wilt, plants were cut down to observe any ooze or vascular bundle discoloration, respectively. However, for plants that had atypical BXW and Fusarium wilt symptoms or recently infected, it was extremely difficult for the CKWs to confirm presence. Such plants, also known as 'asymptomatic plants', require laboratory diagnosis to accurately identify causative pathogen. The laboratory diagnostic protocols used in this study have been and are still employed to accurately detect BXW and BBTD (Mwangi et al. 2007; Tripathi et al. 2007; Adriko et al. 2012; Nakato et al. 2013).

Our results showed that farmers were able to recall some of the management options but that knowledge of disease symptoms and management options was not comprehensively understood, despite a suite of campaigns in Uganda by the national and local governments, international organizations and NGOs that targeted BXW (Bagamba et al. 2006; Karamura et al. 2006; Tushmereirwe et al. 2006). The current resurgence of BXW in Uganda is testament to the fact that previous initiatives have failed to impact farmer practice towards controlling this disease, because of lack of practical advice and lack of continual surveillance (Kubiriba et al. 2014). The advantage of CKW reaching out to farmers is that a service-based approach can be adopted rather than the current project-driven approach (Wambugu et al. 2001; Nyakuni 2001; Raussen et al. 2001). The establishment of projects to tackle epidemics of diseases that are ravaging crops, food security, and potential for income generation is clearly not working. Project activities usually target small groups and lack strategies for scaling–up (Okali et al.1994; Veldhuizen et al. 1997; Kitz 1998; Hawkins et al. 2009; thus, the need for partnerships with telecommunication companies for ICT based agricultural extension services (Hanumankar 2011) that encourage an open agricultural communication process (Colle 2011) is urgent.

There was continuous interaction between the CKW and farmers since both CKW and farmers were from the same village community. This kind of setting encouraged continuous interaction and sharing of information between the CKWs and the farmers and made reporting of results a lot easier since the CKWs were constantly interacting with the farmers. Similarly, since CKWs were obtained from different farmer based organisations, through focus group discussions, information on banana disease management was shared to the larger group. Also, during the revalidation visits, farmers had the opportunity to dialogue further with the technical team on how best to manage diseases on their banana farms.

There is high potential to limit the impact of disease spread by field surveillance through mobile phones and to develop the networks that increase the efficiency of disease management. These networks help to bridge the current gap between scientific research and farming practices. Furthermore, enhanced field surveillance through interventions such as the CKW initiative permits research organizations to recognize risks of disease spread earlier and to deploy the control measures that are necessary to prevent catastrophic disease epidemics. Such an approach is not limited to agriculture, also effective infrastructural networks have been developed that augment information exchange and enhance communication and innovation in service delivery (Parikh et al. 2007; Donner 2009; Tickner 2009).

Agriculture extension program managers could use this tool to develop detailed schedules through the use of interactive maps and customizable digital forms. This system would provide a transparent means for managers or donors to measure field staff and CKW effectiveness based on monitoring performance through area coverage, data quality indicators and farmer evaluations of extension services. Lastly, farmers owning mobile phones could receive SMS alerts regarding relevant information and most importantly would have a direct communication link to an integrated research based agriculture extension program.

To ensure effective agricultural extension, more transparent and participatory networks need to replace the current top-down approach in developing countries. This study has shown the potential for an alternative network that is a reliable model for community level crop disease surveillance. Such an integrated and holistic network combines farmers' knowledge, GIS, mobile phones, database management, data analysis and CKWs. This study has also generated valuable knowledge on banana disease distribution and farmers' knowledge that is useful to researchers, government departments and extension.

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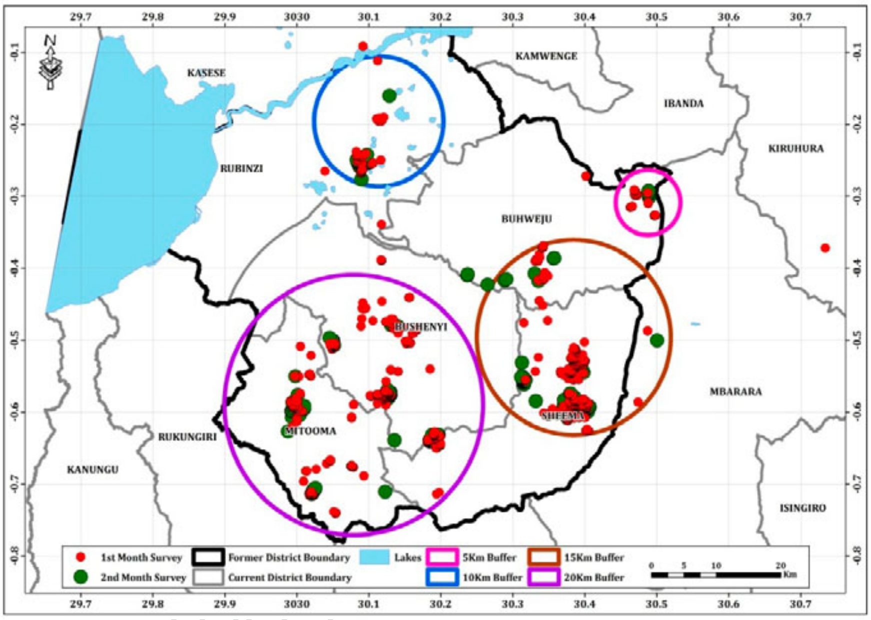
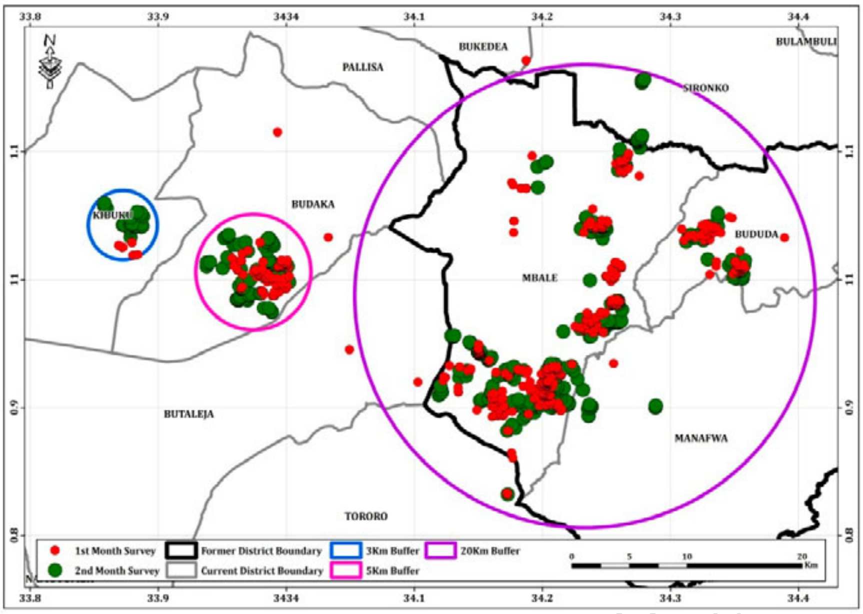
**Fig. 1.** Survey locations in Bushenyi (A) and Mbale (B) districts located within a 5 km radius of the community knowledge worker's home. First and second month survey points are in red and green, respectively, while the buffer zones represent a given number of farms as indicated in the excel sheet.

**A**



**B**




| Buffer zones | Mbale: Single Points | 3 | 5 | 20 | Total | | Bushenyi: Single Points | 5 | 10 | 15 | 20 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month 1** | 170 | 7 | 121 | 529 | **827** | | 24 | 29 | 54 | 341 | 427 | **875** |
| **Month 2** | 23 | 30 | 90 | 469 | **612** | | 14 | 10 | 43 | 205 | 432 | **704** |

**Fig. 2.** Proportion of farms in Bushenyi and Mbale districts of Uganda that were revisited to validate if the community knowledge workers correctly identified and reported accurate incidences for Banana *Xanthomonas* wilt (BXW), *Fusarium* wilt (FW) and Banana bunchy top disease (BBTD) during the 2009 survey.

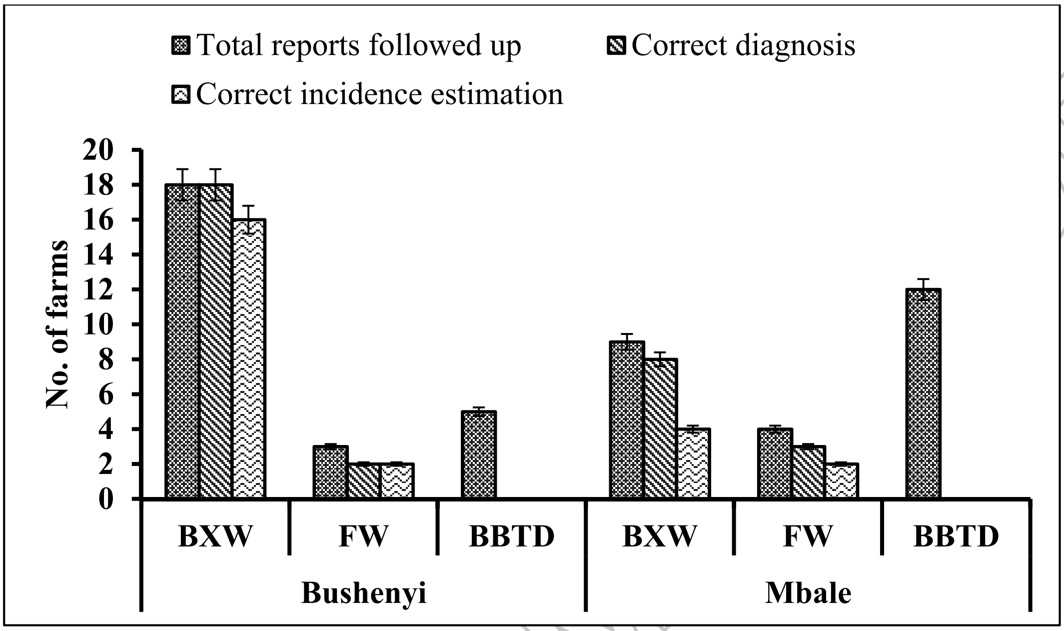


**Fig. 3.** Percentage frequency of the nature of information that farmers would like to access using their mobile phones in the Bushenyi and Mbale districts of Uganda.

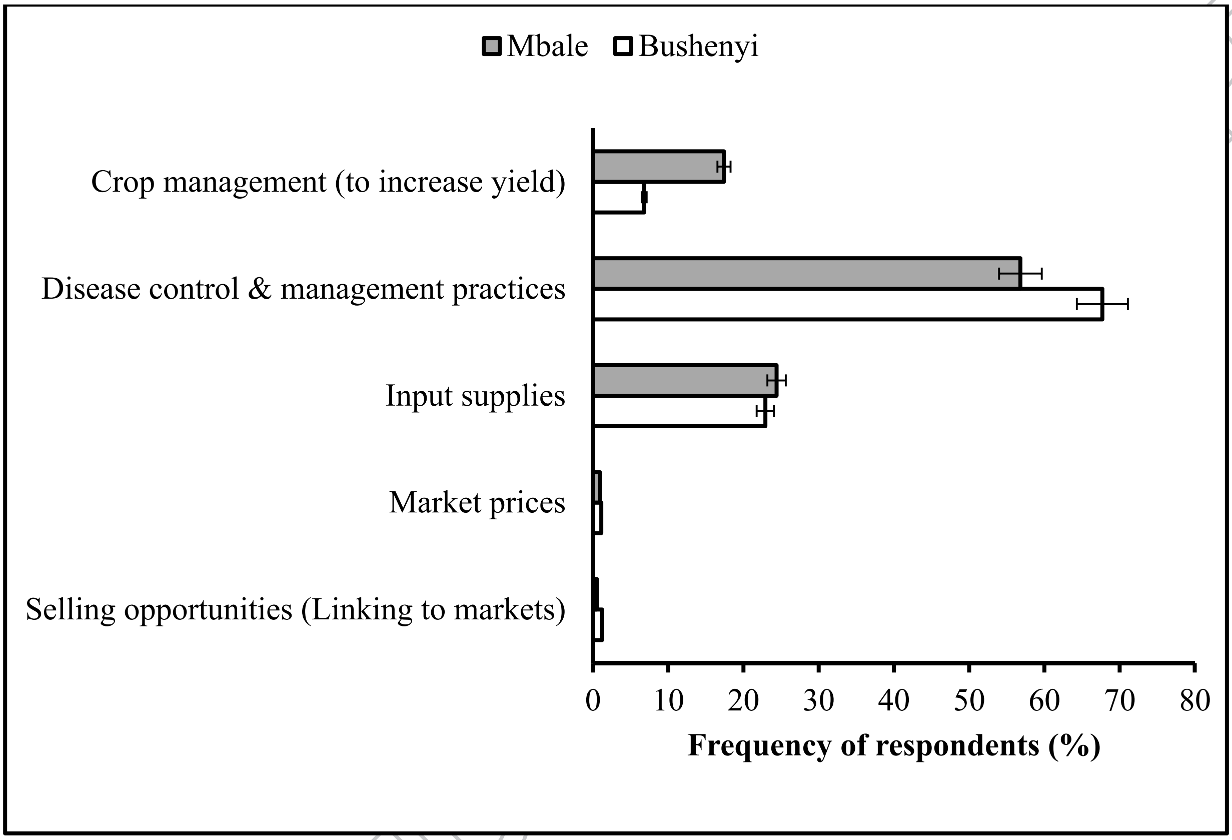


**Table 1.** Name and description of the community based organizations in Bushenyi and Mbale districts from which the 38 Community knowledge workers (CKWs) were sourced for this study.

| Organisation | Description |
|---|---|
| Uganda National Agro-Inputs Dealer Association (UNADA) | Non-profit organization working to strengthen network of rural input suppliers and promote use of inputs to improve farmer productivity. UNADA has a network of multiple input suppliers located in trading centers and rural villages. |
| TechnoServe | BMGF grantee working to develop business solutions in the banana, cotton, fresh produce, and dairy sectors in Uganda. TechnoServe has a network of over 380 farmer's groups |
| Busoga Rural Open Source Development Initiative (BROSDI | Local NGO with over 400 knowledge brokers in two districts that could be integrated into the CKW network. |
| National Agricultural Advisory Services (NAADS) | Government agency of extension agents mandated to serve smallholder farmers operating in every district in Uganda. |
| Farmer Associations:<br>SNV, BUDAFA, Mbale Farmers' Association | Highly active regional farmer associations in the Bushenyi and Mbale districts of Uganda |

**Table 2**. Frequency (%) of farms with Banana *Xanthomonas* wilt (BXW) and *Fusarium* wilt (FW) infection in Bushenyi and Mbale districts of Uganda surveyed in 2009.

| District | BXW | | FW | |
|---|---|---|---|---|
| | Bushenyi | Mbale | Bushenyi | Mbale |
| Disease incidence (%) | 74.9b | 68.8a | 29.1c | 33.8c |
| Lsd (5%) | 4.8** | | $5^{NS}$ | |
| Se | 45.1 | | 46.6 | |
| CV% | 63.4 | | 146.1 | |

Means followed by the same letter within a row are not significantly different at P = 0.05.

Disease incidence (%) was calculated as the percentage quotient of number of diseased plants to the total number of plants on the farm.

NS denotes no significant difference at $p \leq 0.05$ within the columns. ** denotes significant differences at $p \leq 0.01$.

**Table 3.** Farmers' knowledge of and ability to identify plants showing symptoms of Banana *Xanthomonas* wilt (BXW), *Fusarium* wilt (FW) and Banana bunchy top disease (BBTD) in Bushenyi and Mbale districts of Uganda.

| Banana disease | Proportion of responses (%) | | | |
|---|---|---|---|---|
| | Knowledgeable on biotic constraints | | Knowledgeable on management practices | |
| | Bushenyi | Mbale | Bushenyi | Mbale |
| BBTD | 1.7a | 2.6a | 1.7a | 5.2b |
| BXW | 82.3c | 77.7c | 69.5f | 41.6e |
| FW | 54.7b | 23.7b | 34.7d | 14.6c |
| Lsd | 2.6*** | | 2.6*** | |
| CV% | 90.2 | | 138.1 | |

Means followed by the same letter are not significantly different at 5% Lsd. *** denote significantly different at $p \leq 0.001$, respectively.