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# Usage of Mobile Phones for Crop Pest Surveillance in Kenya, Case of Uasin Gishu County

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**Abstract**

In Kenya, Uasin Gishu County is known to be one of the breadbasket counties due to high and reliable rainfall. According to the county's integrated development plan (CIDP) for 2023-2027, the emerging of new strains of pests and diseases has been listed as one of the challenges facing agriculture sector in the county. This has made small holder farmers not able to maximize on crop yields. Therefore, crop productivity in the region is currently declining due to the use of traditional mechanisms to mitigate and control emerging crop pests and diseases, and their effects. This has further been aggravated by the effects of climate change in the region. The study adopted both qualitative and quantitative based approach and targeted ninety-six small holder farmers. Questionnaires were administered using semi-structured interviews and observation. To optimize full benefits of technology, the farmers in the region need to make use of mobile phone technology which is readily available locally and used by many farmers in their communities in meeting the demands for rural livelihoods, market related strategies and collaboration efforts by use of phone related applications. There is need to support the small holder farmers to improve on crop yields by leveraging the use of mobile phone technology. This paper was guided by two objectives. To begin with, we explored how mobile phone technology has been used for crop pest surveillance in the county. Secondly, we came up with a pest surveillance model for small holder farmers to address their local needs. The findings from the study show that by use of a mobile phone technology and other related web tools, the small holder farmers can connect with other stakeholders such as the agrovets and extension workers who are critical in providing solutions affecting them on crop pest management and surveillance. It is crucial to develop and leverage on new tools and technologies to support early detection and diagnosis of crop pests and diseases before they cause adverse losses. Kenya based pest surveillance model is proposed to be used in ensuring that small holder farmers can connect with other stakeholders by use of mobile phone in facilitating exchange of information critical in pest management and disease surveillance.

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## Introduction

International Livestock Research Institute (ILRI),[1] notes that population growth in Africa has grown from 476 million in 1980 to around 1.4 billion in 2021. They projected that Africa would have a population of 2.5 billion by 2050 and a great proportion of this will be living in urban areas. The future of farming in Africa is uncertain due to the continent's pressing food concerns. The small holder farmers in sub-Saharan Africa lacks the potential of turning around the economic fortunes because of the current polices put in place. The farms in the region are highly fragmented and this will continue due to the increase in population. With proper investment in agriculture sector, the paper notes that economic development in the region can be realized and especially growing urban centres that puts pressure on neighbouring farmlands to obtain adequate food.

In Kenya Fact Sheet paper, United States Agency for International Development (USAID)[2] notes that agriculture is the main economic activity whereby 75% of its citizens rely on agriculture to earn a living. Furthermore, agriculture sector accounts for more than 25% of the country's Gross Domestic Product (GDP). Despite agriculture sector in Kenya being a backbone to the economy, this has not been doing well in the recent years coupled with increasing population. Also, the farming land in Kenya has been reducing significantly due to land defragmentation and only about 20% of the land is used in agriculture. Many farmers are noted to be working on the farms using outdated technology and lacking adequate financial and extension services.

Looking at the above factors, there is need to develop crop farming surveillance solutions using mobile phones to support specifically small holder farmers improve their crop yield and tackling crop pest related problems with ease. By assessing effects of global warming, insect pests are prone to destroy staple grains such as maize, wheat and rice. There is a close relationship between temperature and population growth and metabolic rates of insects. As a result of this, crop pests are expected to increase by 10% to 25% per degree of global mean surface warming.[3] This study incorporates mobile farmer-based technologies, the farmers, extension workers and the agrovets would be linked so that the farmers are able to receive the appropriate method in mitigating against crop losses caused by crop pests disease invasion.

The common traditional method mainly in use in plant pests and disease detection and identification was the human eye which most of the time was done by the experts in the community. However, this method is not reliable because it is time consuming and becomes costly when dealing with large farms. Furthermore, human eye inspection is complex. To overcome this challenge, there is need to use mobile phone technology to detect plant disease automatically using image processing techniques especially during the early stages with more accuracy. Real time tool such as mobile phone enables the small holder farmer to take the corrective action before the problem becomes difficult to contain thereby preventing crop losses and spread of the disease. The major steps involved in the image processing techniques are image acquisition, image pre-processing, image segmentation, feature extraction, and classification of the disease.[4,5]

Most smallholder farmers struggle in mitigating crop pest losses because they do not have adequate capacity in addressing the invasion of emerging pests and diseases. This problem is aggravated due to lack of mechanisms to report crop pest invasion in real time, regions affected and how to deal with the invasion. Thus, there is need to empower the farmers with tools and techniques to identify, mitigate and control crop pests, and access to continuous learning platform to curb new and emerging crop pests that may not be familiar to them. To strengthen learning, there is need to collaborate with other stakeholders in the sector such as agriculture extension worker, agro vets and other research institutions. Given the ever-increasing adoption of mobile phones (both the smart phones and basic feature phones), this study argues that we can leverage the increasing advancement in mobile phone technology and telecommunications to develop mobile phone-based solution towards placing information and knowledge into the farmers' hands. Mobile phone would also be beneficial during collaboration efforts with all stakeholders involved in controlling and mitigating against crop losses.

In view of mitigating crop losses using a digital tool such as mobile phone and enabling collaboration efforts, the research questions addressed in this paper are as follows:

- What is the usage of mobile phones for crop pest surveillance in Uasin Gishu County, Kenya?
- How can we design pest surveillance model for small holder farmers in Kenya?

**Related Work**

Red Palm Weevil (RPW) which attacks date palm is one of the most dangerous pests. To counter the pests, it is always ideal to conduct surveillance on time and early detection. One of the preventive measures of doing this is by conducting close investigations on individual trees or by population dynamics trapping the RPW. The study leveraged geotagging of the surveillance and trap data to develop structured geo-database which maps and monitors the dynamics of the pest. The results are fed into the quantification of vulnerability of date palms to RPW risks in advance and across the scales with innovative use of Big Data and ICT tools such as smartphones. These observations were further taken into Spatial Data Analytics (SDA) to assess pattern and behavior of the pest. However, this study is challenged by data gaps collected in one of the farms. They note further work in analysis using past data with special emphasis on population trends, risk factors associated with climate and management practices, and employing blockchain technology in surveillance of the pests.[6]

In the study above by Biradar,[6] the main tasks that were conducted during the initial phase were to develop and demonstrate geotagging of field data and tree level information. Secondly, data organization and geo-linking of the field data to farm typologies and finally developing spatial models of RPW risks and web analytics for monitoring and management. The geodatabase at trees and farm level referencing were used to generate time-step hotspot analysis of RPW. Their results indicated approximately 23% of the farms infested with the pest (RPW) and almost 31% of the farms were found to be suspected of the pest. Further analysis showed that 57% of the farms were likely to be infested by the pests if no action was taken. This study, however, noted some data gaps which require further analysis with historical data such as population characteristics, climate, and management aspect to ascertain the risks involved and measures mitigating against the RPW infestation. This study required high resolution satellite data in cloud computing domain to make real-time analytics a reality. This therefore demands for a sensitive multi-functional DSS that is scalable and user-friendly for selecting appropriate management measures in developing strategies that solves sustainable date palm farming systems.

Singh and Gupta[7] noted that e-Pest surveillance system utilizes the use of internet in capturing pest information from fields and generates immediate and customized pest reports to the experts to advise the state agriculture agencies who further reach out to the concerned farmers. For the farmers in remote based areas, the system was customized to allow offline data entry. The system allows experts' feedback to the farmers to be disseminated by use of text messaging (SMS). This system helps in collecting the data, providing offline data entry, data verification and capture into the database, online reporting, and provision of pest advisories to the farmers. The challenge noted with the system is that this is customized to the State Department of Agriculture as the target.

To have timely response during crop pest invasion, the surveillance data may need to be interpreted by experts or other technical advisors within a short span of time. This is because delay in relay of immediate feedback could result in unnecessary loss of production. Some of the gaps noted in this model is that it becomes to implement this in places where there are limited experts. Furthermore, the model is not scalable and there is need that the interpretation to be automated so that the system becomes scalable.[8]

A proposed framework for e-surveillance of crop pests provides information to farmers on pest and disease control, and extension services. This framework is extended and developed as Digicult platform – a digital solution to empower farmers to curb Fall Armyworm (FAW) and its effects as shown in Figure 2. It is noted that extension workers can use the digital tool, local agrovets stores, government, and other interested parties to combat FAW. The platform has three major components to oversee e-pest surveillance: the web-based application, mobile application, and SMS- USSD service. It is highlighted that the Digicult App has a light-end image processing module which automatically detects the presence of FAW on the crop. In their study, the framework brings together the local small holder farmers, agro-vet stores, and extension services workers in a database. In this case, when a farmer faces a problem, he can seek the services of a local agro-vet store or a farm extension worker for assistance. The platform allows both farmers in possession of smart phone and non-smart phone the ability to obtain information from the server. Methods of access could be through the simple messaging system (SMS), Digicult App and by use of a short code which captures the characteristics of a specific insect (USSD) sent to the server for interpretation. In this work some of the assumptions made do not make sense, for example it assumes that the farmers will just use the system in solving their needs, but it does not show how the farmers will be motivated to use the application in terms of cost incurred in connecting to the server and accessing the USSD. It also does not explain how the server will be hosted and its related costs. Furthermore, the solution does not support working offline especially farmers working in remote area with no internet. [9]

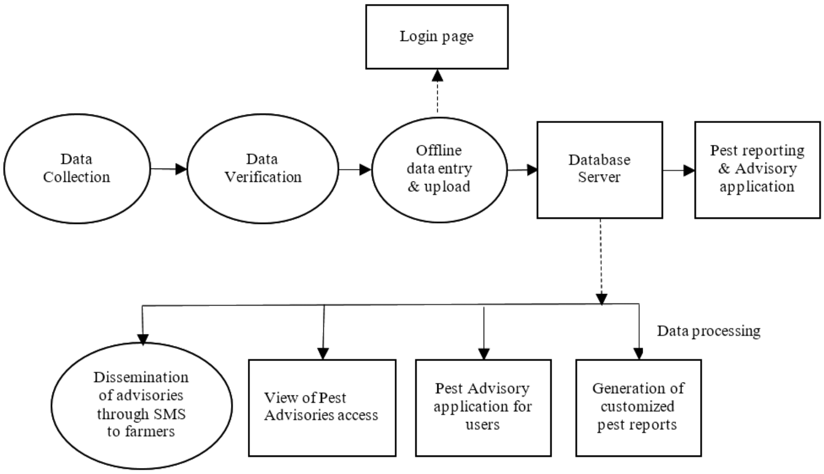


**Fig 1: Architecture of e-pest surveillance under Cropsap (Vennila, [8])**

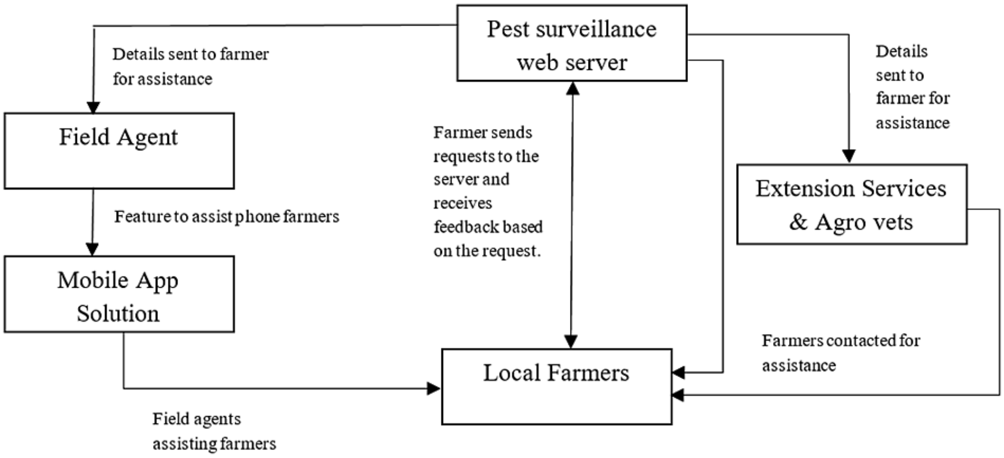


**Fig. 2: Mobile phone-based Pest Surveillance for Fall Army Worm (Awuor F, Otanga S, Kimeli V, Rambim D, Abuya T)**

In many developing countries like Kenya, crop farmers check their crops and pastures with a weeding hoe on hand. However, an integrated approach to pest management is important in controlling unwanted pests. Regular monitoring of pests assists in determining population levels to improve management decisions Farm Biosecurity.[10] In their study on trends in plant science, Stenberg,[11] notes that Integrated Pest Management (IPM) is used in combating plant pests and diseases using several approaches, while minimizing applications of chemical pesticides. The study noted that the founders of IPM recognized that integrating several methods to combat pests would require further research with key stakeholders whose objective is to focus on single plant protection methods. According to USDA,[12] IPM is not a single pest control method but has the components of evaluations, decisions, and control. It proposes that IPM follow a four steps approach which are setting pest control actions, monitoring, and identifying pests, prevention using cultural methods (rotating between different crops, using pest resistant varieties and planting pest free rootstock) and control methods such as targeted bait applications or the spraying of pesticides. IPM has been noted to be used by farmers in preventing pesticides resistance and keeping the costs low. One of the drawbacks that is associated with IPM compared to traditional pest control techniques such as spraying is that farmers must be trained to understand the IPM methods and how this can be effectively applied in controlling the pests and diseases.[13]

## Materials and Methods

This study adopted both quantitative and qualitative methods in data collection. A survey questionnaire was administered to ninety-six small holder farmers. The questionnaire was administered to the crop farmers by the researcher using semi-structured interviews and observation. The interviews provided an opportunity to get details in depth and this lasted for almost an hour per farmer. Semi structured interviews allowed precise data collection due to the respondents beliefs and the motivation regarding the specific issues to be addressed. This allowed for follow-up questions and more information was gathered. The responses obtained from the completed questionnaire were coded. This study was conducted in Uasin Gishu County. This is because the county has been experiencing emerging pests and disease such as the case of fall armyworm which started invading the county in 2018. The study targeted small holder crop farmers in Kesses Sub County because other sub counties such as Moiben and Ziwa engage in large scale farming. Apart from maize production, Kesses and Ainabkoi sub counties are also known in growing Irish potatoes more than the other sub counties.[14] Stratified sampling technique was used to select three wards in Kesses Sub County that have had the highest hit of emerging crop pests. This technique also allowed the researchers the opportunity to obtain the sample population from the three out of four wards which made adequate representation of the population. Targeted sampling was used to select respondents (farmers) who have experienced the greatest loss due to crop pest in the recent past 1-3 years. Here, the interest were farmers who in one way or another experienced loss directly from crop pest and disease invasion, hence the use of targeted sampling. To ensure reliability and validity for the data collected, the research instrument was piloted at Ainabkoi Sub County. Furthermore, reliability of the questionnaire was accomplished by use of Cronbach's alpha of 0.8 mean. Cronbach's alpha is a measure of internal consistency while using Statistical Package for the Social Sciences (SPSS) statistics. In its interpretation, a mean of between 0.6 to 0.7 indicates an acceptable level of reliability while 0.8 or greater indicates an exceptionally satisfactory level of reliability. Descriptive statistics were used to analyze the data collected from the respondents. These included the use of percentages and frequency distribution. Analysis of variance (ANOVA) was used to evaluate the level of significance of the variables on the dependent variable at 95% confidence level. These variables included total size of the farm, land available for crop farming and cultivated land across the seasons. These were quantified in acres. For the open-ended questions (qualitative data), content analysis technique was applied. Here, if the answers were captured on the tool and looked similar, coding of values was used to assign the different variables and analysis done by combining variables that have similar interpretation. For example, while tackling usefulness of mobile phone to crop farmer in providing crop farming business information, several answers were received such as quick access to information, learning and collaboration, search services among others. Themes of similar meaning were put together and assigned a code and these made analysis work while using SPSS easier. Ethical considerations were put in place whereby crop farmers participated voluntarily when the researcher informed the subjects about the methods which will be used to enforce anonymity and confidentiality and explain why the study is conducted purely for educational purposes only. The crop farmer was also notified of the freedom to withdraw anytime without any repercussions.

## Results and Discussion

This section presents the data collected from the field, their analysis and discussion. The study explored the potential of ICT tools in providing information access to farmers by leveraging mobile technology in Kesses Sub County, Uasin Gishu County. The data is presented in the form of text, tables, figures, and percentages. The data was collected through face-to-face interviews and questionnaires which were administered to the respondents. Some of the areas of focus during the data collection included farmer land use information, mode of crop farming information to crop farmers, agricultural extension services, mobile phone use in dissemination of crop farming information, and crop pest surveillance characteristics in the study area.

### Farmer Land Use Information

With rising population, most areas associated with high agricultural potential have led to reduction in land acreage under other crops.[15] Agricultural land fragmentation and continued increase in population, has led to reduction in agricultural land posing challenges to food security.[16]

**Table 1: Descriptive statistics for the land use**

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| The total size of farm(s) | 96 | 0.20 | 12.00 | 3.1677 | 2.72430 |
| Land available for crop farming | 96 | 0.10 | 6.00 | 1.9490 | 1.49773 |
| Cultivated land in season one | 96 | 0.10 | 6.00 | 1.6500 | 1.19827 |
| Cultivated land in season two | 96 | 0.10 | 6.00 | 1.6917 | 1.25881 |
| Valid N (listwise) | 96 | | | | |

From table 1, the mean value for the total size of the farms stands at 3.2 acres. The mean value for the land available for crop farming stands at 1.95 acres constituting 61.5% of the total farm size. On the other hand, the land cultivated in both seasons stands at a mean of 1.7 acres which is 85% of the tillable land. This implies that the adoption of mobile phone technology would be so handy to the smallholder farmers who form the major category of the population.

### Mode of Crop Farming Information to Farmers

Mobile phone, television and radio were perceived as effective in communication than other sources such as agriculture websites, computer, helplines and landlines.[17] Farmers who complement video with an interactive voice response (IVR) service, were performing much better in applying agricultural knowledge compared to those who receive videos without IVR or short message services (SMS) messages.[18]

Table 2 shows that most farmers at 32.5% receives information through farm visits, 21.7% through mobile phones, 17.2% through meetings, 6.4% through written materials, 3.8% through farmer short courses and 2.5% through radio or television. The aim of understanding the information sources available to crop farmers is to identify the main sources and how this is conveyed to the farmer which will form the basis for support in using modern ICT technology.

### Mobile Phone use in Dissemination of Crop Farming Information

According to Kumar,[19] farmers in the region have been using mobile phones for more than 3 years. This has assisted in accessing agricultural information such as post-harvest, weeding, thinning and storage. Mobile phones have a significant influence on production level. 20 The benefits derived from using the mobile phone in agriculture include ease of access to farming and marketing information, quick responses from extension agents, usage of mobile apps in detection of crop diseases and farmer participation in online training and seminars. Mobile phone applications assist the small holder farmers to receive immediate feedback from the extension systems whereby focus is on the youth and women in agriculture. This platform provides enabling environment for knowledge sharing with the involved stakeholders.[21]

**Table 2: Mode of crop farming information to farmers**

| How communicated was conveyed to farmer | Responses | | Percent of Cases (%) |
|---|---|---|---|
| | N | Percent (%) | |
| Information conveyed through farm visits | 51 | 32.5 | 53.1 |
| Information conveyed through meetings | 27 | 17.2 | 28.1 |
| Information conveyed through mobile phones | 34 | 21.7 | 35.4 |
| Information conveyed through written materials | 10 | 6.4 | 10.4 |
| Information conveyed through farmer short courses | 6 | 3.8 | 6.3 |
| Information conveyed through radio or television | 4 | 2.5 | 4.2 |
| Not applicable | 25 | 15.9 | 26.0 |
| Total | 157 | 100.0 | 163.5 |

**Table 3: Mobile phones use in dissemination of crop farming information**

| Characteristics | Frequency (N=96) | | Percent |
|---|---|---|---|
| Used mobile phones to source for agricultural information | Yes | 45 | 46.9 |
| | No | 51 | 53.1 |
| Access crop pests related information | Yes | 39 | 40.6 |
| | No | 57 | 59.4 |

From the above data in table 3, farmers at 47% are using mobile phones to source agricultural information in Uasin Gishu County. Also, 41% of the small holder farmers access crop pests' related information. These results show that almost half of the population are utilizing mobile phone to source agriculture information. This number is adequate to support local solution of using mobile phone (research question 1) in crop pest surveillance. This study therefore supports mobile phones in playing a critical role in making access to information achievable thereby enhancing crop pest surveillance by small holder farmers. Here, the assumption is that through cross learning and government interventions, more farmers will be attracted to mobile phone ownership and the uptake of use in pest surveillance will drastically increase.

**Crop Pests Information Accessed using Phone**

Panda, notes that advances in application of ICT in crop pest and disease management is made possible by use of advanced technology. This has made it possible for the farmers to receive real time information on crop disease, pest monitoring and advisory services.[22] In their work on transformative role of mobile applications in empowering smallholder farmers, Kamal and Bablu confirmed that mobile apps have provided real-time access to targeted agricultural information, current weather conditions, crop prices, desired farming practices, and techniques of handling crop pests.[23]

**Table 4: Types of crop pest information accessed**

| Crop Information Accessed | Responses | | Percent of Cases (%) |
|---|---|---|---|
| | N | Percent (%) | |
| Pests and disease control | 34 | 26% | 35% |
| Available Pesticides in the market | 14 | 11% | 15% |
| Frequency of applying pesticides | 10 | 8% | 10% |
| Types of pests affecting the region | 14 | 11% | 15% |
| Not applicable | 58 | 45% | 60% |
| Total | 130 | 100% | 135% |

Table 4 shows that 26% of the farmers access pest and control information, 11% access both pesticides in the market or types of pests affecting the region while 8% are accessing the frequency of applying pesticides. However, a substantial number of farmers, 45% do not access crop farming information. These findings show that small holder farmers are finding it useful to use mobile phones in assisting them get viable information on crop pest management in Uasin Gishu County.

**Seeking Agricultural Extension Services**

Food security situation can be improved by adoption of mobile phones which support easy and accurate agricultural knowledge sharing with other stakeholders such as the agricultural extension workers.[24] With mobile phone ownership in Kenya farming households at 98%, agricultural extension services will find more adoption by the farmers especially when receiving advice from the experts.[25]

**Table 5: Correlation between mobile phone internet access and use of mobile phone in seeking agricultural extension services cross tabulation.**

| Characteristics | | | Used mobile phone in seeking agricultural extension services | | Total |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Mobile access internet | No | Count | 39 | 5 | 44 |
| | | % With Mobile phone internet access | 88.6% | 11.4% | 100.0% |
| | Yes | Count | 31 | 21 | 52 |
| | | % With Mobile phone internet access | 59.6% | 40.4% | 100.0% |
| Total | Count | 70 | 26 | 96 | |
| | % With Mobile phone internet access | | 72.9% | 27.1% | 100.0% |

In table 5, 21 farmers with access to internet are using their phones in seeking agricultural extension services. This represents a proportion of 40.4%.

Figure 3 shows the graphical representation for the farmers seeking agricultural extension services in Uasin Gishu County and owning a phone either with internet access or not. This shows that farmers with mobile phones with access to internet who are seeking agricultural extension services are at 40.4% while those having phones with internet access, yet they are not seeking agricultural extension services are at 11.4%. This data shows the readiness of the farmers to utilize mobile phones in seeking agricultural extension services. Building of solution to crop farmers problems will require a framework that incorporates all the stakeholders. This assist to address research question two.

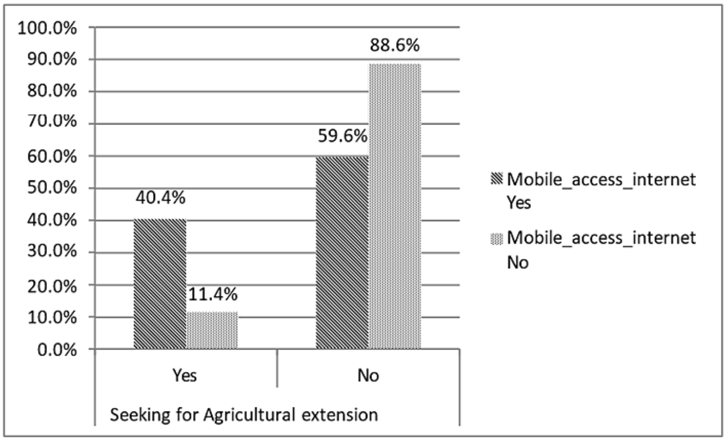


**Fig. 3: Farmers seeking agricultural extension services using internet enabled mobile phones**

### Social Media Platforms Accessed by Farmers

In bridging understanding of farmers access to information, farmers use online sources in accessing soil information.[26] New products in the market such as a pesticide, can be accessed through social media platforms thereby facilitating new learning about the product quality and its usage.[27] During Covid-19 pandemic, farmers were able to use mobile phones in accessing agricultural related information using social media platforms such as Facebook, Zalo, YouTube and many more.[28] The farmers were able to access market information, weather updates, extension advisory services, new farming techniques, and contacts to farm input suppliers.

**Table 6: Social media platforms used by farmers in Uasin Gishu County**

| Characteristics | | Responses | | Percent (%) of Cases |
|---|---|---|---|---|
| | | N | Percent (%) | |
| Social media platforms used by farmers | Facebook | 47 | 32.9 | 49.0 |
| | WhatsApp | 41 | 28.7 | 42.7 |
| | Twitter | 8 | 5.6 | 8.3 |
| | YouTube | 1 | 0.7 | 1.0 |
| | Not Applicable | 46 | 32.2 | 47.9 |
| Total | 143 | 100.0 | 149.0 | |

Analysis from table 6 reveal that majority of farmers, 32.9% are using Facebook, 28.7% use WhatsApp, 5.6% use Twitter and 1% use YouTube. However, 32.2% of the farmers are not using social media platforms. These are farmers who are using other means of communication to achieve access to information, for instance use of agricultural extension services, radios, and televisions. Therefore, while using mobile phone in solving crop pest management issues, social media platforms can be used to disseminate emerging threats in crop farming.

In table 7, multiple response analysis show that daily, 43.8% of the farmers access WhatsApp, 40.6% access Facebook, 6.3% access YouTube and 5.2% access Twitter. On a weekly basis, 10.4% of the farmers access YouTube, 8.3% access Twitter, 7.3% access Facebook, 4.2% access WhatsApp and 1% access other social media. In terms of using mobile phones in accessing social media monthly, 7.3% of the farmers access YouTube, 2.1% access Twitter, 2.1% also access Facebook and 1% access WhatsApp. Every Quarter, 2.1% of the farmers access Facebook and 2.1% again access Twitter. This analysis suggests that almost half of the farmers access the two popular social media sites (Facebook and WhatsApp). In building the farmer-based solution, in crop pest surveillance, there is need to incorporate social media tools in disseminating valuable information to the farmers using a mobile phone.

**Table 7: Frequency of using mobile phone in accessing social media**

| Characteristic | Daily | | Weekly | | Monthly | | Quarterly | |
|---|---|---|---|---|---|---|---|---|
| | Count | Subtable Total N (%) | Count | Subtable Total N (%) | Count | Subtable Total N (%) | Count | Subtable Total N (%) |
| Frequency of WhatsApp use | 42 | 43.8 | 4 | 4.2 | 1 | 1.0 | 0 | 0.0 |
| Frequency of Facebook use | 39 | 40.6 | 7 | 7.3 | 2 | 2.1 | 2 | 2.1 |
| Frequency of Twitter use | 5 | 5.2 | 8 | 8.3 | 2 | 2.1 | 2 | 2.1 |
| Frequency of YouTube use | 6 | 6.3 | 10 | 10.4 | 7 | 7.3 | 0 | 0.0 |
| Frequency of others use | 0 | 0.0 | 1 | 1.0 | 0 | 0.0 | 0 | 0.0 |

**Usefulness of Mobile Phone in Providing Crop Farming Information**

Mobile phone-enabled agricultural information services (m-Agri services) in Africa, benefits include supporting farmers to access financial services, farm input, practices and the prevailing market prices.[29] Low-cost digital technologies are key drivers in improving the farmers information sharing and access to vital information in real time which can be available in rural locations.[30]

**Table 8: Usefulness of mobile phone in providing crop farming information**

| Ways in which phone info was useful | Responses | | Percent (%) of Cases |
|---|---|---|---|
| | N | Percent (%) | |
| Not applicable | 40 | 27.6 | 41.7 |
| Usefulness of mobile phone in quick access to information | 6 | 4.1 | 6.3 |
| Usefulness of mobile phone in learning from other farmers on best practices | 10 | 6.9 | 10.4 |
| Usefulness of mobile phone in searching right information for crop management | 39 | 26.9 | 40.6 |
| Usefulness of mobile phone in providing alerts by SMS to guide farmers | 11 | 7.6 | 11.5 |
| Usefulness of mobile phone in linking farmers with agrovets, researchers and other stakeholders | 4 | 2.8 | 4.2 |
| Usefulness of mobile phone in marketing farmers produce and seeking other marketing strategies | 8 | 5.5 | 8.3 |
| Usefulness of mobile phone in other aspects | 27 | 18.6 | 28.1 |
| **Total** | **145** | **100.0** | **151.0** |

Analysis from table 8 demonstrates usefulness in mobile phone use whereby 26.9% use the phone in searching the right information for crop management, 7.6% use the mobile phone in providing alerts by SMS to guide the farmers. Moreover, 6.9% of the farmers use the mobile phone in learning from other farmers on best practices, 5.5% use mobile phones in marketing farmers produce and seeking other marketing strategies and 4.1% of the farmers are using mobile phone in accessing information faster. However, 27.6% of the farmers do not find mobile phones useful in providing crop farming business information. These insights support the use of mobile phone technology in giving the farmers equal access to services that are crucial in making crop farming meaningful. Therefore, farmer-based solutions are required and would also link the usage of mobile phone technology.

### Challenges Farmers Face in using the Mobile Phone

The barriers which limit the use of ICT devices such as mobile phones by the banana farmers include low literacy levels, high cost in purchasing the devices and inadequate technical skills.[31] Low digital literacy rates in agriculture, portable web network conditions and digital tools maintenance are some of the factors limiting optimal use of digital tools in agriculture.[32]

**Table 9: Challenges faced while using the mobile phone**

| Challenges faced while using phone | Responses | | Percent (%) of Cases |
|---|---|---|---|
| | N | Percent (%) | |
| Use of language not well understood by the mobile user | 5 | 3.0 | 5.7 |
| Not applicable | 1 | 0.6 | 1.1 |
| Charges incurred on text messages, phone calls and data bundles | 66 | 39.1 | 75.0 |
| Phone charging done too frequently | 9 | 5.3 | 10.2 |
| Lack of understanding in using some functionalities on phone | 6 | 3.6 | 6.8 |
| Poor network coverage | 43 | 25.4 | 48.9 |
| Lack of electricity by phone user | 35 | 20.7 | 39.8 |
| Other challenges | 4 | 2.4 | 4.5 |
| **Total** | **169** | **100.0** | **192.0** |

Table 9 analysis reveals that key challenges include 39.1% of the responses who are affected by cost and related phone charges, and this represents 75% of the cases. Also, 25.4% of the responses are affected by poor network coverage, 20.7% affected by lack of access to electricity. This data shows that despite mobile phone uptake and use by the small holder farmers, there are noted challenges associated with them. In this regard, the farmers can employ several options to counter these challenges. They include lobbying with internet service providers to lower costs of data bundles especially towards the farmers. Also, other stakeholders and farmer partners can support the farmers' needs in providing airtime or data required for accessing the internet including smart phones. Internet service providers in Kenya are required to increase the number of masts and towers especially in rural areas to boost signal strength and network coverage. The government can also ensure electricity coverage to many households is achieved through last mile connectivity (case of Kenyan government) in rural areas.

### Crop Pest Control Methods

According to Ghosh and Wilkinson,[33] to reduce the reliance of pesticides which are harmful to the environment, there is need to adopt biological pest control. By employing this approach, the natural pest predators will assist in regulating the crop pests. However, this method is not effective because it lacks efficiency and effectiveness through which predators can be found and evaluated. In their work, Wang and Jannesari, recommend crop pest control system which is based on the Internet of Things (IoT). In this case, light trap technology and ozone sterilization are employed in the proposed system to help in controlling insect pest and diseases of the agricultural crops. The system consists of IoT enabled sensors to help in collecting environmental information in real time.[34]

**Table 10: Crop pest control methods**

| Pest control methods used by the farmers | Responses | | Percent (%) of Cases |
|---|---|---|---|
| | N | Percent (%) | |
| Spraying using pesticides, fungicides, and other chemicals | 78 | 38.8 | 82.1 |
| Weeding | 44 | 21.9 | 46.3 |
| Intercropping | 5 | 2.5 | 5.3 |
| Crop rotation | 40 | 19.9 | 42.1 |
| Ash | 5 | 2.5 | 5.3 |
| Early planting or timely planting | 11 | 5.5 | 11.6 |
| None | 6 | 3.0 | 6.3 |
| Include use of detergents | 12 | 6.0 | 12.6 |
| **Total** | **201** | **100.0** | **211.6** |

In table 10 above, farmers in Uasin Gishu County at 38.8% control pests by spraying the crops using pesticides, fungicides, and other chemicals. Also, 21.9% use weeding, 19.9% employ crop rotation, 6% use detergents, 5.5% practice early or timely planting, 2.5% use ash, 2.5% use intercropping and 3% do not use any pest control methods. By use of farmer-based technologies, the farmers, extension workers and the agrovets would be linked so that the farmers are able to receive the appropriate method in mitigating against crop losses caused by crop pests disease invasion.

**Table 11: How to use mobile phones in controlling and mitigating crop pests in farms.**

| Use phones to control & mitigate pests | Responses | | Percent (%) of Cases |
|---|---|---|---|
| | N | Percent (%) | |
| Phone calls | 22 | 18.2 | 22.9 |
| Farmer solution applications | 20 | 16.5 | 20.8 |
| Immediate response or feedback | 7 | 5.8 | 7.3 |
| Short message service | 20 | 16.5 | 20.8 |
| Internet search services | 9 | 7.4 | 9.4 |
| Farmer tutorials and notes | 2 | 1.7 | 2.1 |
| Farmer alerts | 4 | 3.3 | 4.2 |
| Collaboration using social media tools & other knowledge sharing channels | 9 | 7.4 | 9.4 |
| Unstructured Supplementary Service Data function | 1 | 0.8 | 1.0 |
| None | 21 | 17.4 | 21.9 |
| Other mitigation methods | 6 | 5.0 | 6.3 |
| **Total** | **121** | **100.0** | **126.0** |

**Using Mobile Phones to Control and Mitigate Crop Pests**

In their work, Awuor and Otanga[35] notes that mobile phone based agricultural innovations can be customized to support farmers in availing information such as land preparation, pre-harvest and post-harvest techniques and marketing of the farm produce. Agricultural apps can effectively be used in agri-business resulting in increased profits for the farmers.[36]

Analysis from table 11 above most farmers at 18.2% would like to use phone calls in controlling and mitigating crop pests in their farms. Furthermore, 20% would like farmer application solutions to be used. Also, 20% prefer to use short message service (SMS). Nine percent of the farmers would like to use internet search services as well as use collaboration/social media tools and other knowledge sharing channels standing at the same 9%. At 7%, the farmers would like immediate responses or feedback by using phones, 6% by use of other mitigating methods, 4% providing farmer alert services, 2% would like to use farmer tutorial and notes, 1% prefer Unstructured Supplementary Service Data (USSD) function and 21% were not able to provide any specific method through which mobile phones could be used in controlling and mitigating crop pests.

In the above analysis from Table 11, most cases at 22.9% prefer to use phone calls in controlling and mitigating crop pests in the farms. Therefore, use of mobile phones will play a critical role in ensuring the farmers are receiving the much-needed services. However, a small proportion of farmers at 1% prefer using USSD services as they prefer short message services in comparison. Therefore, in developing farmer-based applications, it will also be necessary to include solutions with short message functionalities. Mobile phone use and pest control solutions can mainly be mitigated using phone calls, farmers solution applications and short messages as per the data obtained in Uasin Gishu County.

**Crop Pests' Solutions and Techniques**

Farmers can opt to use preventive actions or direct control methods in providing interventions against crop pests.[37] In response to Covid-19 pandemic, 38 digital solutions empower small holder farmers in building resilience of food systems, support extension services on pest management, best practices in agriculture, mobile money solutions in buying farm input as well as receiving payments, play a vital role in supporting the farmers. Farmers have been able to use cultural methods as well as botanical pesticides in controlling pests.[39] Also, conventional synthetic pesticides are commonly used by farmers and are applied on the crops using a knapsack sprayer.

**Table 12: Crop pests control solutions**

| Crop pest control solutions or techniques | Responses | | Percent (%) of Cases |
|---|---|---|---|
| | N | Percent (%) | |
| Ash | 3 | 2.2 | 3.1 |
| Not applicable | 69 | 51.5 | 71.9 |
| Farmer applications | 2 | 1.5 | 2.1 |
| Early planting | 6 | 4.5 | 6.3 |
| Crop rotation | 21 | 15.7 | 21.9 |
| Weeding | 17 | 12.7 | 17.7 |
| Spraying | 16 | 11.9 | 16.7 |
| **Total** | **134** | **100.0** | **139.6** |

Analysis of data from table 12 shows that farmers at 15.7% suggested use of crop rotation, 12.7% suggested use of weeding, 11.9% were in favor of using spraying methods, 4.5% felt early planting was the solution, 2.2% suggested use of wood ash and 1.5% felt that by use of farmer specific applications was the solution. This work will require farmers to be sensitized on appropriate crop pest surveillance techniques or solutions to effectively enable them to become aware of the right solutions. This will be disseminated through different channels and specifically mobile phone technology.

**Influence of Mobile Phone use on Crop Farming Efficiency**

Mobile phone use ranked best compared to other ICT tools.[40] This was delved in terms of providing better agricultural information, improved farming skills, accurate provision of information, improved communication, timely information, and easy access to information.

**Table 13: Influence of mobile phone use on crop farming efficiency**

| Description (Count=N) Agree | Strongly Disagree | | Disagree | | Not sure | | Agree | | Strongly | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | N % | N | N % | N | N % | N | N % | N | N% |
| Increased speeds, reliability, & accuracy of information on exchange between farmers & other stakeholders | 4 | 4.2 | 6 | 6.3 | 21 | 21.9 | 19 | 19.8 | 46 | 47.9 |
| Ability to undertake self-directed crop farming & marketing | 2 | 2.1 | 5 | 5.2 | 23 | 24.0 | 32 | 33.3 | 34 | 35.4 |
| Contact with customers thus providing market for my farm produce | 6 | 6.3 | 6 | 6.3 | 25 | 26.0 | 33 | 34.4 | 26 | 27.1 |
| Access of farming information & making inquiries for improvement of standards | 5 | 5.2 | 5 | 5.2 | 28 | 29.2 | 40 | 41.7 | 18 | 18.8 |
| Increased crop production because of information received via phone | 3 | 3.1 | 7 | 7.3 | 28 | 29.2 | 36 | 37.5 | 22 | 22.9 |
| New forms of knowledge transfer over the internet is possible | 3 | 3.1 | 8 | 8.3 | 40 | 41.7 | 23 | 24.0 | 22 | 22.9 |
| Receive information regarding crop pest disease & management | 3 | 3.1 | 6 | 6.3 | 37 | 38.5 | 29 | 30.2 | 21 | 21.9 |

Table 13 shows that most farmers at 47.9% strongly agree with the fact that speed, reliability, and accuracy of information exchange between farmers and other stakeholders have been increased by mobile phones. Very few farmers at 4.2% do not agree with this fact. In terms of using mobile phones to undertake crop farming and marketing, 34 out of 96 farmers at 35.4% strongly agree on this aspect while the least number of farmers at 2.1% strongly disagree. Again, 26 farmers who agree to have been able to get into contact with customers for the produce using mobile phones thus having ready market for farm produce represent 27.1% while the least number of farmers at 6.3% disagree. In addition, 18.8% representing the highest number of farmers agreed to have accessed the farming topics in mobile phone and make calls to ask questions on how to improve farming standards. However, 5.2% strongly disagreed with the idea. The highest number of farmers, at 37.5%, agree that the application of the farming information obtained through phone has led to increased crop production in farm. On the other hand, the least number of farmers at 3.1% strongly disagree. Many of the farmers at 41.7% are not sure whether new forms of knowledge transfer have been made possible through the internet where farmers are able to access information regarding their farming business. The least number of farmers at 3.1% strongly disagree with this idea. Finally, at 38.5%, most of the farmers are not sure whether they receive information regarding crop pest disease and management. On the other hand, the least number of farmers at 3.1% strongly disagree that they receive crop pest and disease management information.

**Kenya Pest Surveillance Model**

In addressing question 1 of this study on usage of mobile phones for crop pest surveillance in Uasin Gishu County, this section gives more insights using field data analyzed here. To start up with, in table 2 most farmers at 21.7% receive information that is useful to them in crop farming. Also, a substantial number of farmers at 40.4% (table 5) seek agricultural extension services by use of mobile phones that have access to the internet. Moreover, analysis from table 3 shows that a great proportion of farmers at 47% are using mobile phones to source for agricultural information which include pests and disease control, availability of pesticides in the market, frequency of applying pests and finding out the types of pests affecting the region.

Content analysis technique was applied in tables 8, 9, 10, 11, and 12. Here, the answers were captured on the tool and coding of values was used to assign the different variables taking into consideration their similarity. Analysis was then done by combining variables that have similar interpretation using SPSS. Analysis from table 5 show that mobile phone plays a critical role to more than 50% of the farmers because a great proportion of this farmers have access to the internet, they can access social media tools, and they see mobile phone information as useful in their day to day lives. This idea is supported in table 8 whereby about 41% of the farmers see the usefulness of mobile phone in searching for the right information for crop management.

In getting a deeper understanding of the mobile phone in seeking external services, table 5 notes the greatest proportion of farmers at 46% who are seeking information from the agro vets. In seeking more information on frequency of using mobile phone in accessing social media, table 7 shows that greater proportion of the farmers at an average of 42.2% access both WhatsApp and Facebook daily.

The major challenges faced by the crop farmers have been described on table 9, whereby 39.3% of the farmers are constrained with charges incurred on text messages, phone calls and data bundles. Again, most farmers at 25.4% are affected with poor network coverage. The other challenge which the crop farmers are facing is lack of access to electricity to support them in charging their mobile phones and this stands at 20.7%. To counter the listed challenges, the network providers in Kenya are encouraged to lower down the cost of sending messages or making phone calls or internet bundles. This can be supported through farmers' initiatives, collaborations and government policies which address the needs of the farmers to lower down on the costs. Also, the government should continue availing themselves of projects that bring electricity to rural and other marginalized areas through initiatives such as last mile connectivity.

Mobile phones used in controlling and mitigating crop pests in farms as shown on table 11 support the development of farmer solution applications and use of short message services at 16.5%. Again, phone calls play a critical role at 18.2% in controlling and mitigating crop pests in the farms. Therefore, the facts above support the use of mobile phones for crop pest surveillance. This is because a great proportion of the farmers find the use of mobile phone useful in connecting them with other stakeholders while engaging in crop farming, marketing, quality improvement, new knowledge and skills, crop pest disease and management.

In supporting research question 2, this study proposes the use of Kenya based pest surveillance model whereby the government of Kenya should prioritize the use of mobile phone devices by farmers in conducting crop pest and disease surveillance. When a new emerging pest is detected in the country, quick appropriate actions need to be undertaken to safeguard the interest of the crop farmer. Here, the crop farmer is at the center of focus. It is good for a country to respond at an early stage before the pests invade many farms with devastating effects. This is key to protecting our plant resources and ensuring stability in our economy. Therefore, pest surveillance is the chief cornerstone which ensures that food security in our country remains stable and that our environment is also protected from harmful pests and diseases.

The Kenya Pest Surveillance solution (KPS) will be the solution to address small holder farmer pest surveillance needs. Here, the farmer will capture the image of the affected crops in the field using an integrated mobile phone application which is then uploaded onto the main server for processing and analysis. The agriculture extension workers, research workers and other stakeholders who collaborate with the farmers can also take images of crops and upload them onto the server for processing. Based on the plant algorithm, the system generates alerts to the farmers, extension as well as research farmers on a real time so that they can immediately deal with the identified issues. The system provides a module to support mobile SMS alerts and recommendations by the area agricultural extension worker.

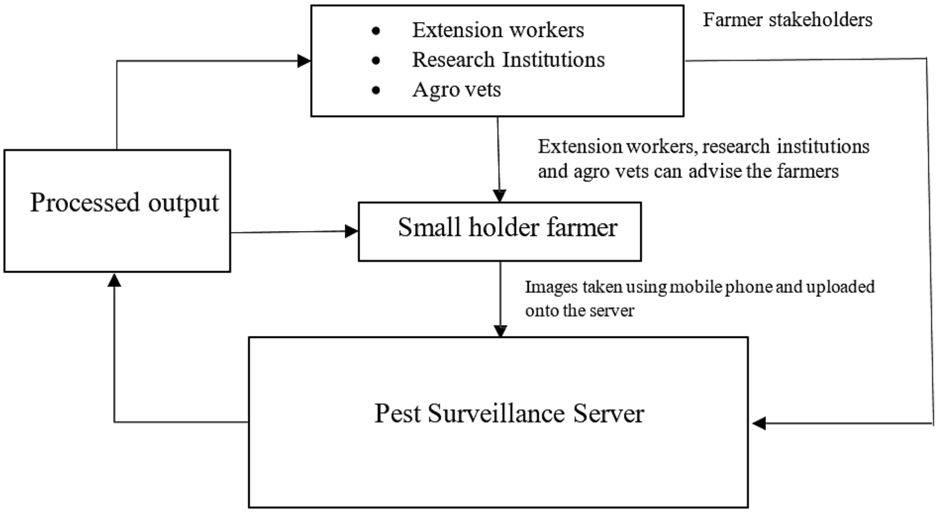


**Fig. 3: Kenya based pest surveillance model (Source: Researcher)**

Figure 4 shows how the process takes place. Here the solution is triggered when the farmer or other stakeholders shown below uploads the image on the Pest Surveillance Server. This server contains element of machine learning which processes and analyses pest and disease management in a brief period. The location specific data will also be captured when the farmer or any other farmer stakeholder shares the uploaded image on the server. This location specific data will be stored in the main database to facilitate ease of access and retrieval. This server can send feedback to both the farmer and the nearby farmer stakeholder within that region. Once the message reaches the extension officers, remedial action is taken immediately.

## Conclusion

By looking at information access to small holder farmers, most farmers are accessing information which is useful in supporting their farming practices. In equal focus, farmers are receiving information on crop farming from the ministry of agriculture personnel (extension officers) who visit their farms. With regards to use of internet by the farmers, a great proportion have access to the internet, and they use their phones in accessing them. Also, the farmers with access to internet use their mobile phone in seeking agricultural extension services. Furthermore, farmers who have internet access look at pests and disease control information, among others.

Focusing on mobile phone usage, most farmers find mobile phone information useful, and they allow access to social media tools therefore seeing the usefulness of mobile phone in searching right information for crop management. Some of the main phone services needed to access crop farming include short messages (SMS), making phone calls and use of mobile applications (Apps). The least number of farmers do not require mobile money services in their phones. A respectable number of small holder farmers access WhatsApp and Facebook as social media tools daily.

The greatest challenge faced by a small holder farmer while using the mobile phone is charges incurred on text messages, phone calls and data bundles. Another notable challenge is poor network coverage and lack of access to electricity.

The main pest control method used by the small holder farmers are spraying using pesticides, fungicides, and other chemicals. The other notable pest control methods include weeding and crop rotation. In trying to understand how farmers use mobile phones in controlling and mitigating crop pests in the farms, majority of them supported the use of phone calls, farmer solution applications and short message service. With usage of mobile phone on crop farming efficiency, most small holder farmers strongly agree with the fact that speed, reliability, and accuracy of information exchange between farmers and other stakeholders have been increased by mobile phones. Farmers also feel that there is increased crop production because of information received from mobile phone.

By use and adoption of Kenya based pest surveillance model, small holder farmers will be assisted in knowing the kind of crop pest and disease that are invading their farms and taking remedial actions with support from other stakeholders. Therefore, small holder farmers will be empowered in identifying, mitigating, and controlling crop pests and diseases by use of a mobile phone.

In future, this work need to incorporate other advanced farming support systems such as the use of Drone Technology. This means images captured will be more than one prompting changes in the entire model. Also, there is need to involve machine learning resources in scale up and optimization of Artificial Intelligence technologies.

To increase adoption efforts, there is need to collaborate with other stakeholders such as the Ministry of environment, forestry, and natural resources. This would help in scale up of this work to support pests and diseases that affects natural vegetation such as the leaves of the trees, shrubs, and grass. Sometimes, crop pests hide in the nearby trees or grass surrounding the farms. The pest server functions should accommodate all the requirements for the newly added stakeholders.

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**Ethics Statement**
For this work, crop farmers were notified accordingly that their confidentiality and legal rights will be protected, and the study was purely for educational purposes only.

**Informed Consent Statement**
Crop farmers were informed about the methods which will be used to enforce anonymity. The farmers were requested to either proceed or to withdraw without any implications at any time.

**Author Contributions**
- **Michael Songol:** Conceptualization, Writing – Original Draft, Data Collection, Analysis
- **Fredrick Awuor:** Methodology, Writing – Review & Editing, Supervision
- **Benard Maake:** Visualization, Supervision.

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