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Evaluating Farmers Information Needs for Precision Farming in Kinangop Sub County, Kenya

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Abstract-*Current technological developments have seen innovations of pervasive gadgets able to generate a massive amount of data within and without their environment. Agriculture is one of these areas. However, the usage of such data for effective and timely decisions faces great challenges. Many small-scale farmers, though aware of such mechanisms, are not in a position to utilize these data; leading to a continued low return on investment. This study therefore, endeavored to evaluate farmers' information needs to foster small-scale precision farming. With a survey, the data were collected, statistically analyzed and results discussed. Using grounded method, the researchers implemented an interplay of two cycles of data collection and analysis, resulting into four high-level themes; including need for reliable information source, awareness, self-autonomy and technology proliferation as the actual problems facing small-scale farmers in Kinangop Sub County. This research could provide informed approach to farmers and government agencies on how to enact small-scale precision farming.*

Key words: Precision Farming; Data Analytics; Machine Learning; Grounded Theory

Introduction

Today, there is an upsurge in data generations whose usage has become more ubiquitous. Agribusinesses are finding new ways to increase production by optimizing access, analysis, and management of huge volumes of data that can be useful to enhanced sustainable food production (Ribarics, 2016). The utilization of this data can improve efficiency, enhanced and timely decisions. Modern agriculture is becoming a technology driven business. This aligned with the predicted world population of nine billion people by 2050, means that agriculture has to increase food production from less hectares and in sustainable way. Food security would become an important issue in many countries (Vuran et al., 2018). Bold measures are urgently needed to assure a food secure nation. Research has shown that with modern technological advancement, farming can be enhanced, especially on areas of decision making that is proving a problem to many small-scale f[i]armers. This indicates a significant change, making farmers autonomous hence free from relying on extension officers who may not be readily available when needed. With this therefore, private and public sectors alike can utilize sensors to monitor crops and help with the decision-making process on a field-by-field basis (Ribarics, 2016)

Accordingly, optimizing data driven farming could provide increased crop yields due to automated decision making (Patents, 2017). However, a number of hindrances to full data science crop yield optimization exist. These include:" spatiotemporal *data, Heterogeneous Data, Missing Data, and Noisy Data"* (Miles, 2019). This is consistent to our preliminary findings at Kinangop Sub County, Kenya; where we sought to determine if small-scale farmers get maximum benefits from their farming activities. It was however found that lack of soil analysis aligned to knowledge of soil type affected choice of appropriate and available fertilizer. Lack of market information and plantings of which crops were potentially in short supply was another problem. So, farmers were sometimes planting crops that were oversupplied and were therefore losing money on them. Also, availability of certified seeds was not guaranteed, thus affecting yield. Additionally, it appears that the general small size of land holdings has an effect on their access to information and this also affects their purchasing power for inputs. The level of production seems to be on a mainly subsistence level. Climate change was also perceived to be an issue which could possibly be addressed by strategically placed water holding areas to help in times of drought.

Similarly, as weather predictions become more accurate, then the decision-making process of what and when can become enhanced. Also, with more understanding of soil analysis, choice of varieties and better access to certified seeds, then farming will become more sustainable. And with the increase in yields there would be more disposable income that would become available benefiting the area as a whole; potentially making an area more politically stable. Therefore, efficient utilization of data from multiple sources before and through-out the growing season can augment farmers with informed intuitions on their activities(Spyros, 2017).

While, modern technological innovations afford production of enormous agricultural data, able to enhance timely decisions. Usage of such data for effective decisions faces challenges, leading to continued low return on investment. Efficient data optimization can promote yield prediction, a key agricultural concern for farmers; to shift them from traditional methods of using intuitions. This study therefore, endeavored to explore new themes on how to optimize data for increased crop production in precision farming. The study uses grounded method to arrive at the actual problems facing small-scale farmers in Kinangop Sub County, Kenya.

Literature review

Precision farming has been used since the nineties and has taken time to become readily available to farmers(Vuran et al., 2018). The system has been sold in some quarters as a way to reduce input costs. It could be looked at as a way targeting inputs in relation to field mapping, soil analysis and density of crop vegetation in conjunction with satellite/drone imagery and their relation to yield. The collated information can be utilized to target inputs into areas where they are required for optimum crop production. The real-time data collection can help farmers with decision making process through Normalized Difference Vegetation Index (NDVI) for targeting fertilizers, detecting potential pest and disease incidents (Loon & Speratti, 2018). One of the fundamental technologies that could be used to realize precision farming is the artificial intelligence, more precisely, the machine learning paradigm.

In the recent past, Machine Learning (ML) has advanced from exploiting the likelihood of computers learning, to playing games, and now to an autonomous research discipline. The new developments provide required foundation for statistical-computational ideologies of learning procedures and a variant of algorithms for text analysis, pattern recognition, among others (Ribarics, 2016). In addition, it has led to characterizing data mining research interest in identifying hidden meaning. Extant literature exhibits extensive use of Machine Learning algorithms in promoting precision farming. For instance, (Hartati & Sitanggang, 2010) presented a fuzzy-based Decision Support System to assess land fittingness and selecting crops for planting. Accordingly, they used fuzzy rules with the support of a prototype to demonstrate their arguments. In (Dahikar et al., 2015), crop prediction model is presented to predict the right crop by sensing several parameter of soil temperatures and those associated with the atmosphere. The study demonstrates the ability of artificial neural network in estimating and predicting crop yields. In (Paswan & Begum, 2013), a detailed study is made relating traditional statistical methods and feed forward neural networks. Also, a comparison on linear regression and its prediction ability on agricultural crop production is made; offering a practical intuition of neural networks and their statistical equivalents in the crop yield prediction(Taiwo Amoo & Dzwairo, 2016).

In (Mahabadi, 2015), an investigation on whether artificial neural network (ANN) models could efficiently forecast rice potential production calculated with AEZ model is presented. In their study, key parameters used to evaluate the implementation of the ANN included: *"Mean absolute error (MAE), root mean square error (RMSE) and coefficient of determination (R2)"*. Their rice yield model ensued in high performance trained neural network to predict the produce of rice. Also, the sensitivity analysis exhibited that rice potential production had highest dependency on soil PH, organic matter concentration and electrical conductivity; concluding that the proposed model could improve rice yield prediction. In (Pudumalar et al., 2017), the study presents an ensemble technique to combine the power of several machine learning models in order to obtain greater prediction efficiency. In (Ramesh, 2015), the research presents knowledge on the region explicit crop yield analysis by implementing both Multiple Linear Regression technique and Density-based clustering mechanism.

Data analytics are methods used to analyze and gain intelligence from data (Gandomi & Haider, 2015). In agriculture, they provide new insights for onslaught weather decisions, improved productivity and evasion of redundant cost associated to harvesting, use of fertilizers and pesticide (Kumari, 2018). Accordingly, agriculture as one of the key factors for economic growth has seen new studies and distinctive implementations to predict and improve crop yields. For instance, Kinangop Sub County is deemed the bread basket of Kenya due to its high production of cabbages, potatoes, maize and beans that are sold in neighboring towns. However, the productivity of major crops has been on the declining trend accentuated by high cost of certified seeds and fertilizer(Kamau et al., 2015). Low productivity in Irish potatoes, cabbages, peas, carrots and kales is also affected by the heavy dependence on rainfall. Small land holding of an average two hectares is another feature that characterize farming in this region. Moreover, the collapse of many agricultural cooperative societies suggests that cheap inputs that were offered by the cooperatives as a result of scale economies are inaccessible to majority of the member farmers (Kamau et al., 2015). Therefore, data utilization from satellites and drones can augment farmers with informed intuitions on their activities(Bloem et al., 2014). Data analytics for precision farming under irrigation and use of higher yielding varieties and fertilizer could reverse this trend.

Materials and methods

The research used mixed methods triangulation design which is one of the designs that represents more of an approach to examining a research problem than a methodology. Mixed methods triangulation is a two-phase design where the result of the first phase(qualitative) forms the basis for the second phase (quantitative). The exploratory model is used for instruments development. The design begins with qualitative data which is analyzed and results give insights into the kind of questions to place in the research instruments, kind of hypothesis to be tested and the kind of assumptions to be made.

For qualitative design, grounded theory (GT) was found appropriate and therefore used since it provides a broad, interpretive and inductive research method based on symbolic interactionism and naturalistic inquiry. It affords theories to evolve throughout actual research, on constant interplay between data collection and analysis (Mansourian, 2006). According to (Willig & Stainton-Rogers, 2011), GT was developed to counter the growing hegemony of complex quantitative methods that had widened the gap between theory and research in the USA through a methodical way to analyze qualitative data. GT therefore, involves developing theory that is established in data, scientifically collected and analyzed. With this methodology, researchers do not test preconceived hypothesis, but rather, new theories are developed based on systematically gathered evidence.

Further, GT involves the gradual identification and integration of sets of meaning from data and it is both the aspect of category recognition and integration and its product (Glaser & Strauss, 1999). Moreover, GT holds big potential for enhanced adoption for several reasons like providing a platform for qualitative analysis and the ability to be used with many qualitative mechanisms like biographical, ethnographic, or discursive analyses. In addition, GT can enhance view of a single behavior as embedded in social contexts. Further, GT can fit in either constructionist or post-positivist epistemologies. Lastly, GT can bridge qualitative and quantitative traditions in psychology (Glaser, 1965; Glaser & Strauss, 1999). Accordingly, psychologists are moving from atomized studies towards comprehension of varied contexts they live in. Performing a comparison of grounded methods and topic modeling, (Baumer et al., 2017) observe that pure abstract methodical techniques would be hardly possible. They conclude that, each of the methods require some amounts of researchers' independent judgment, in the application process and in the results interpretation. Additionally, several alignments in analysis processes between the methods are identified; with a new model arising even though what is meant in each approach differ considerably.

According to (Glaser, 1965), analysis on grounded theory encompasses the discovery of theory from data. It achieves this through constant comparisons and iterative process on different incidences in the data, to develop conceptual categories and theoretical themes for phenomena description. Category revisions are done severally through repetitively finding counter-examples till the themes can adequately account for what is observed in the data (Baumer et al., 2017). Since we investigate a static set of reviews, the approach can be described as a form of analytic method ensuing grounded theory principles.

With the spirit of grounded method, data were obtained in two phases. First, using a simple questionnaire administered to three informants and later using an on-line survey based on Google Docs with twenty-five respondents. The latter comprised of two sections: one, for personal information and demographics and two, for farmers' perceptions on precision farming. The second phase of data collection resulted to fine-tuning of the theoretical concepts established in the analysis of data gathered in the first phase of data collection. According to (Thomson, 2016), the theoretical point of saturation is influenced by the range of the research questions, the phenomena sensitivity, and the researcher's ability. In their findings however they observe that, for grounded theory, the average sample size of twenty-five was sufficient to fully obtain patterns, categories, properties, concepts and dimensions of a phenomena. Therefore, it is with this in mind that we proceeded to analysis stage, when the responses reached twenty-five.

Results and Findings

The data collected from three informants made up of one male and two female in first phase. In this case thematic questions were posed to respondents in order to obtain relevant information. For instance, they were asked on the possibility of doing soil testing on their farms of which they said that they would have wanted to, but due to distance and lack of proper information, they have not been able to do soil testing. We also sought to know the main crop production constrains, in which several constraints were listed, including lack information on genuine seeds, unpredictable weather patterns, and market information.in addition, we sought to know the main source of agricultural information, where the respondents talked of the agricultural extension officers, fellow farmers and cooperative society meetings retailers, whose information were inconsistent and sometimes misleading. As such, key concepts appeared to emerge, including: soil testing, source of agricultural information, need to self-autonomy in executing agricultural functions free from middlemen and crop production constraints. Consequently, it was expedient to conduct another round of data collection (phase two) from a total of twenty-five respondents to further enhance on the identified concepts. The demographic distribution of data obtained are as shown in **Figures 1-8.** The results were analyzed as follows:

Location/Ward

The results found that Engineer and Njambini wards gave higher respondents of 32 and 24 percent respectively. This could be an indication of higher farming activities in these regions and also higher numbers of informed farmers. This is described in **Figure 1.**

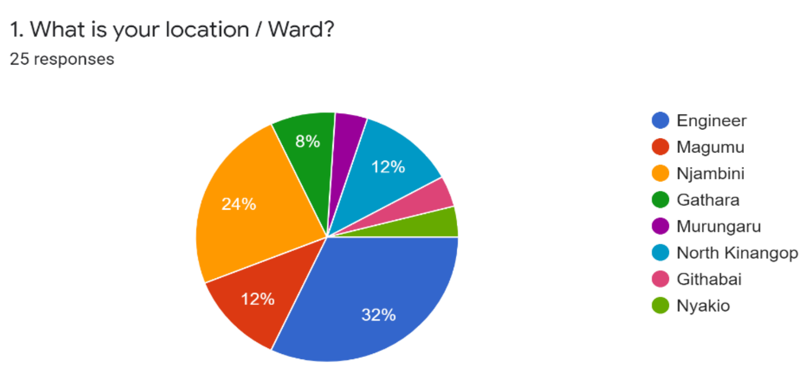

Figure 1: Location/Ward

Gender Distribution

In gender distribution, the male gender represented 68% while their female counterparts were 32%. This is shown in **Figure 2.**

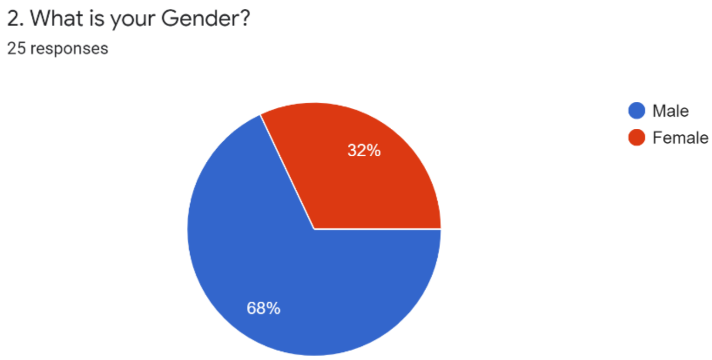

Figure 2: Gender Distribution

Age bracket of respondents

It was notable that majority respondents, 60 percent were between the age of 31 and 50 years of age, followed by those below 30 years. These age brackets prone to usage of smart phones and can easily embrace new technology to boost farming.

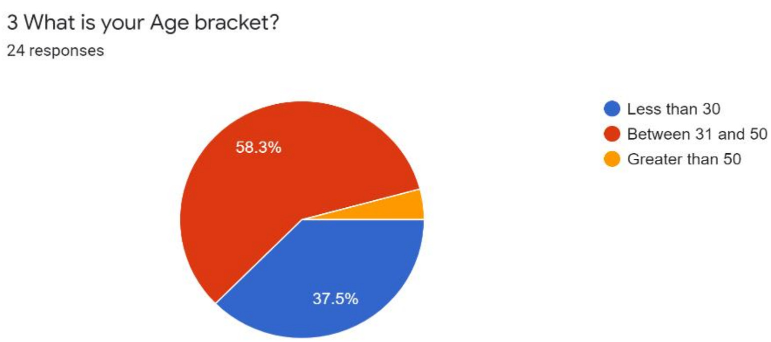

Figure 3:Age bracket of respondents

Level of Education

Majority respondents, 64 percent, had minimum tertiary education and zero respondent with no formal education; a clear indication that farmers in this region are learned and can easily take-up new technology to augment their farming practices.

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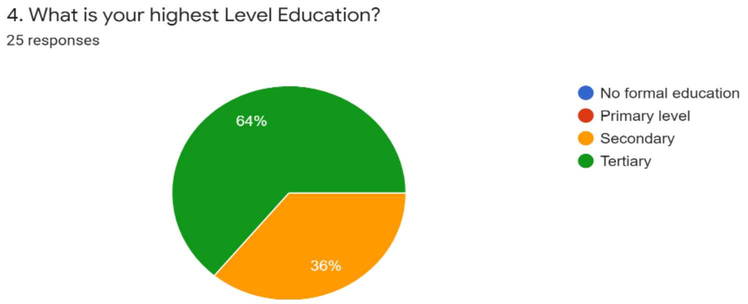

Figure 4:Level of Education

Soil Testing on farm

We sought to establish on whether respondents had ever done soil testing to influence the kind of crops planted on each planting season. The findings indicated that majority respondents, 76 percent had never done soil testing on their farm and only 24 percent had. This indicated the dire need to utilize technology to harness soil testing to eventually improve return on farming.

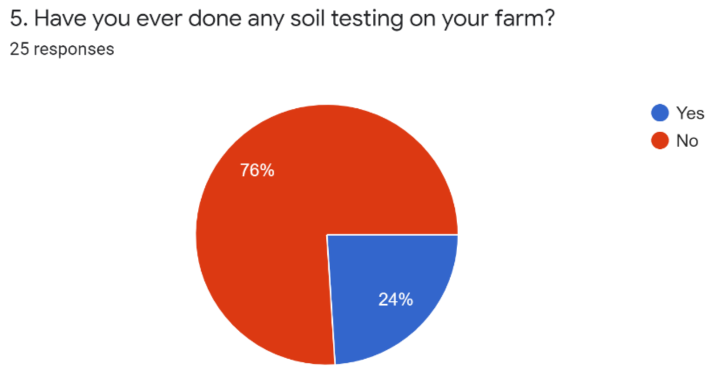

Figure 5:Soil Testing on farm

Main source of agricultural information

Additionally, it is worth noting that the majority respondents, 48 percent, used the Internet and mobile applications as their main source of agricultural information. This is however followed by radio programs at 28 percent and Extension Officers at 20 percent.

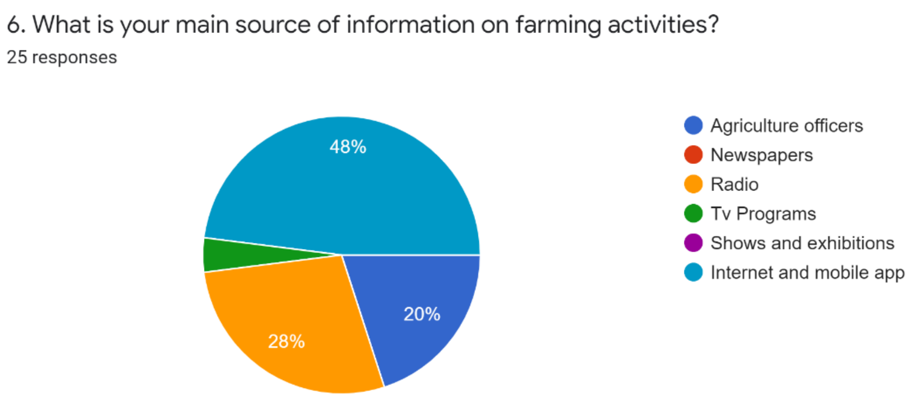

Figure 6:Main source of agricultural information

Main Crop Production Constraints

Market information appeared to be the main production constraint with a high respondent rate of 20 percent. This is followed closely with ways of value addition and information on genuine seeds at 16 percent each. Therefore, this is a clear indication of a dire need to develop and promote mechanisms of addressing such flaws to guarantee maximum return on investment.

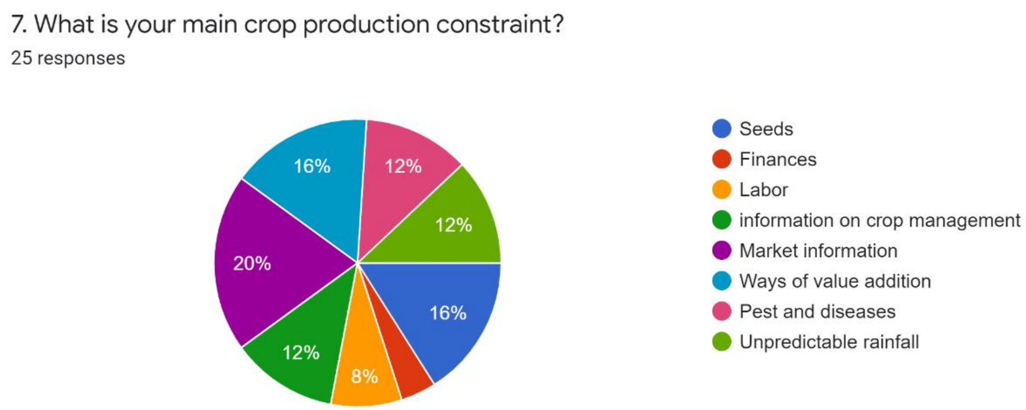

Figure 7:Main Crop Production Constraints

Type of Phone

The findings also indicated higher number of respondents (88 percent), with smart phones and only 12 percent with basic phones. This is shown in **Figure 3.**

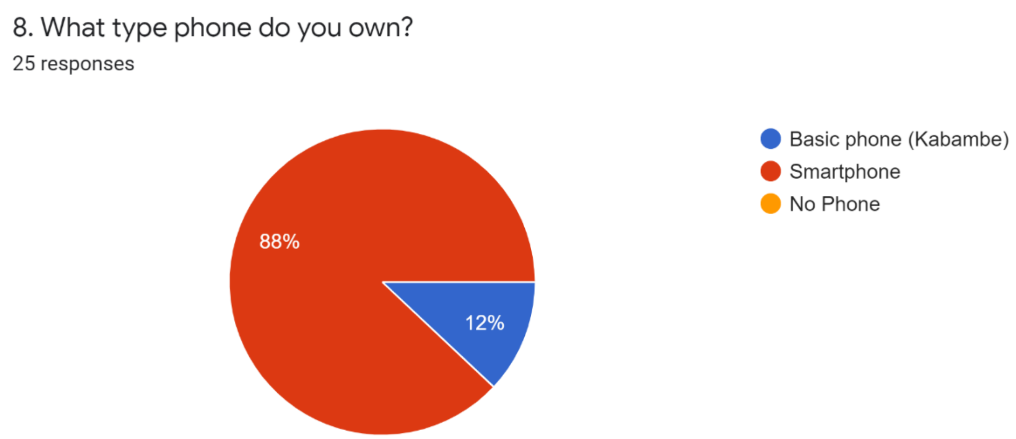

Figure 8:Type of Phone

Formulation of High-level Themes from Findings

On a scale of 1-5 (1=Strongly Agree, 2=Agree, 3=neither agree or disagree, 4= Disagree, 5=Strongly Disagree), respondents were asked to rate the level of agreement for each of the research items presented that related to their farming experiences. The findings from grounded theory analysis bore four high-level themes that establish the conceptual groupings identified in the entire results analysis.

Reliable information source.

We sought response to a number of research items in bid to establish the need for precision farming that support this conceptual grouping. The first of such research items is: "***9. Reliable information would help in planning the next planting season".*** It was found that majority respondents were concerned on how to obtain a number of crucial information necessary to farming as evident on **Figure 9** with a high of 44 percent of those that strongly agreed to the research item. Getting information from co-operative societies, hardly available extension officers and / or from other farmers is unreliable. Similarly, many respondents seek information on accurate rainfall pattern to enable them plan on the next crop to plant. They also need information on the type of fertilizer to apply on their soil, and the type of pesticides and chemicals for their crops. For instance, the fact that majority respondents got advice on fertilizer from Merchants, or Agricultural Extension Officers who were not locally available; is substantial proof that these farmers need alternative, efficient methods. Additionally, soil type and structure are key to enable them plan on the type of crops to plant in the next planting season; the information that could help them preserve tubers.

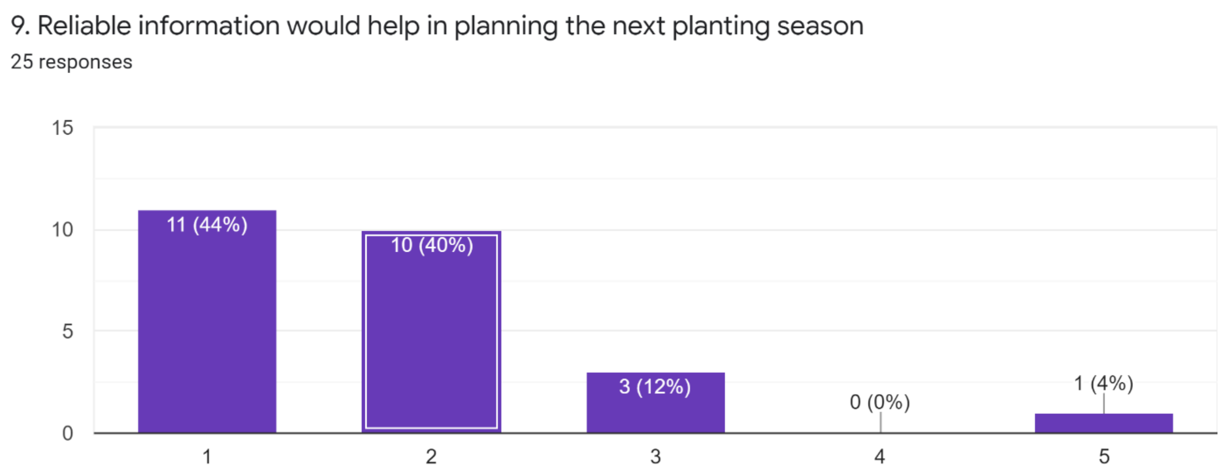

Figure 9: Reliable information would help in planning the next planting season

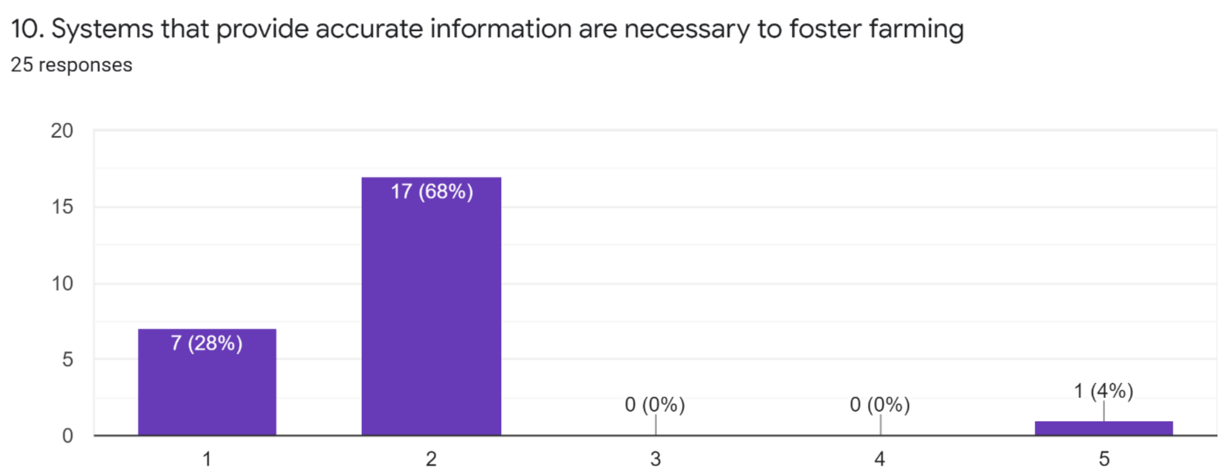

Figure 10: Systems that provide accurate information are necessary to foster farming

Other research items with significant similar results included: “*10. Systems that provide accurate information are necessary to foster farming”* and ***“11. Information on accurate rainfall pattern would aid in planning the next crop to plant”;*** as shown in **Figure 10** and **Figure 11** respectively.

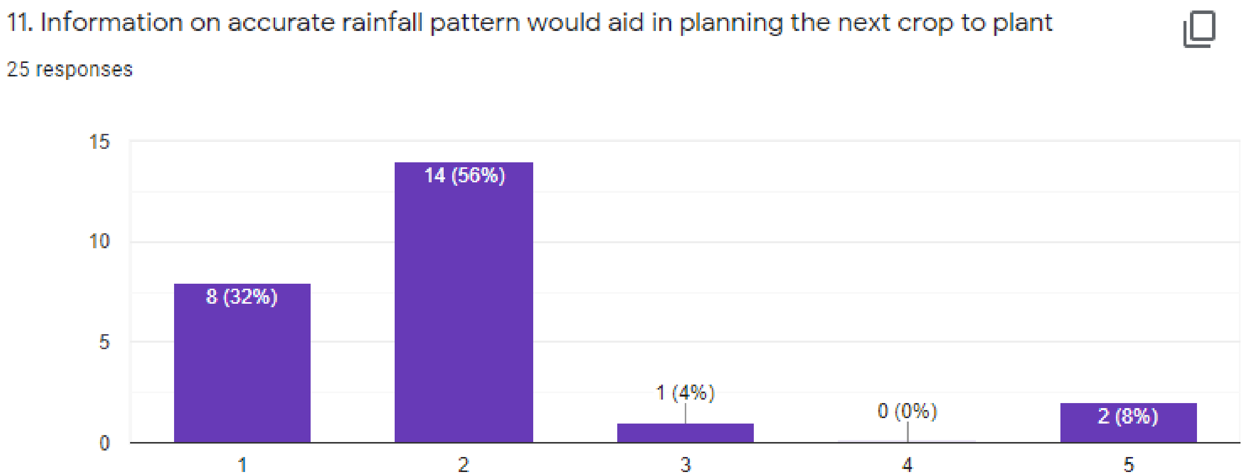

Figure 11:Information on accurate rainfall pattern would aid in planning the next crop to plant

Awareness

This is another conceptual category obtained from the research findings. Consequently, we used the research item “***12. I am aware that certified farm inputs like seeds affects productivity of the farm”*** to determine this concept. The response from this item gave us the output as describe in **Figure 12**. From the respondent’s report, certified farm inputs like seeds are directly proportional to yield. This is supported by a high of 56 percent respondents strongly agreeing to the survey item.

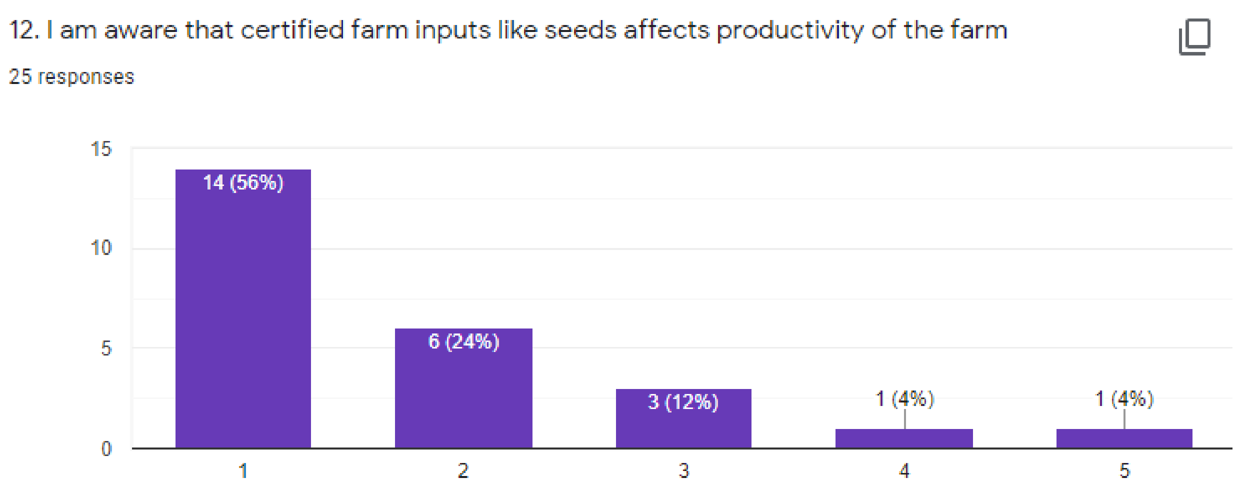

Figure 12: I am aware that certified farm inputs like seeds affects productivity of the farm

Conversely, the research item ***“13. knapsack training kit on spraying is necessary to improve my knowledge on chemical applications”,*** indicated a grave concern that farmers lack basic knowledge on using such key farm tool. Consequently, respondents failed to report the use knapsack spraying training, raising anxieties that they could be exposed to harmful pesticides that might not have knapsack approval.

This is described in **Figure 13**. Nonetheless, some respondents reported as being aware of the soil testing but had not done it on their land to ascertain soil nutrients requirements. This was in response to the research item," ***14. I am aware that soil testing to ascertain nutrients requirements is necessary to improve yield".*** The respondents report is described in **Figure 14.**

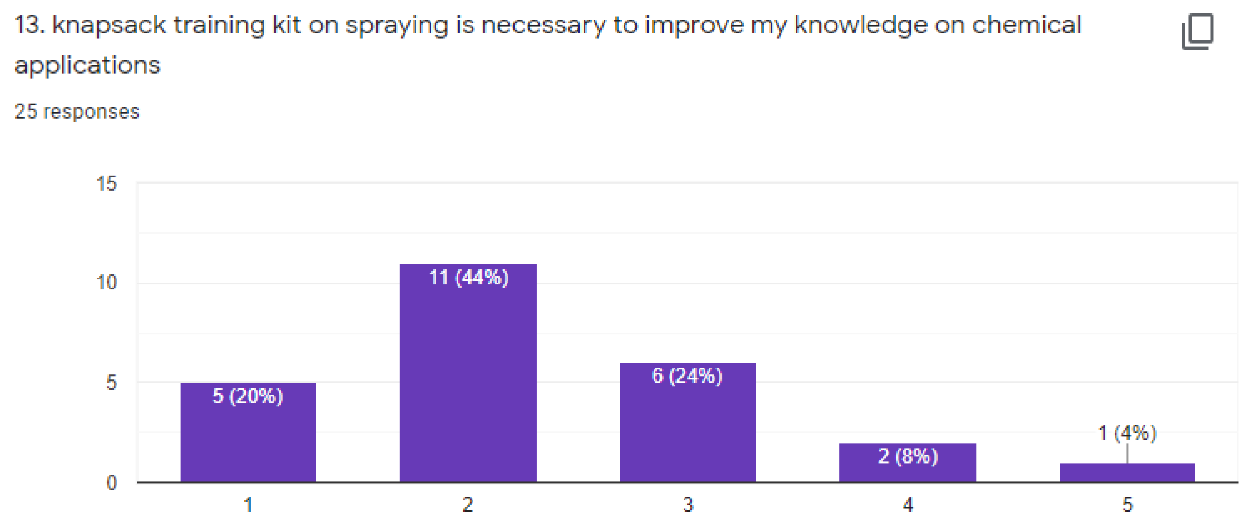

Figure 13: knapsack training kit on spraying is necessary to improve my knowledge on chemical applications

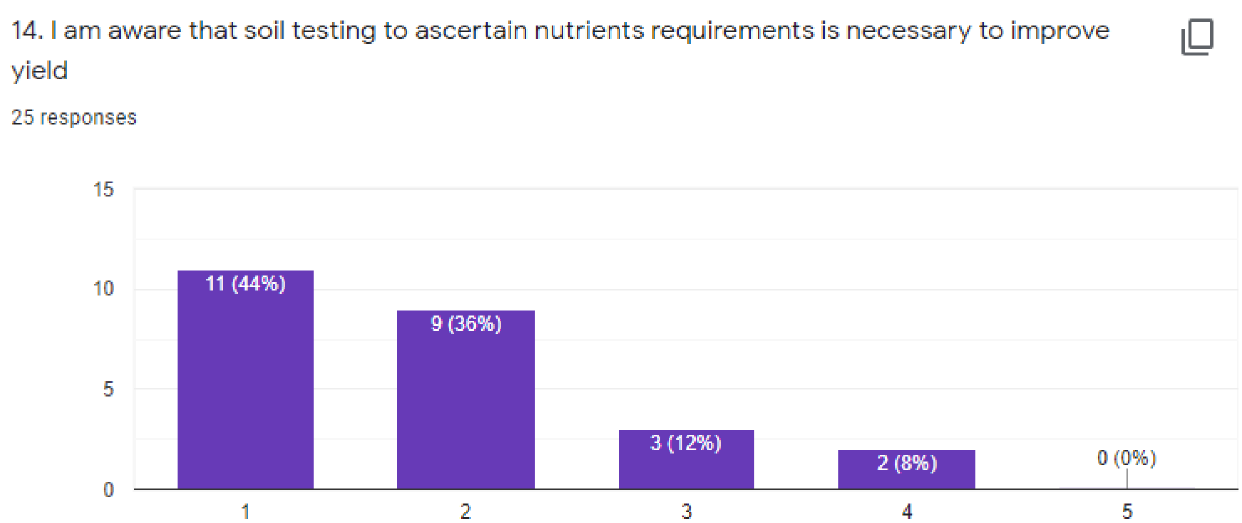

Figure 14:I am aware that soil testing to ascertain nutrients requirements is necessary to improve yield

Self-Autonomy or Control

This is another conceptual category proposed. Farmers would want to do things on their farms without necessarily involving second or third parties. In support of this concept, we sought response on the research item, "***15. I would want to involve middle men in my farming operations".*** The respondents report showed that farmers were uncomfortable with middlemen whom they accused of reaping so much from their effort. This is seen from the higher respondent on the research item, with 36 percent disagreeing with the research

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item. This is described in **Figure 15.**

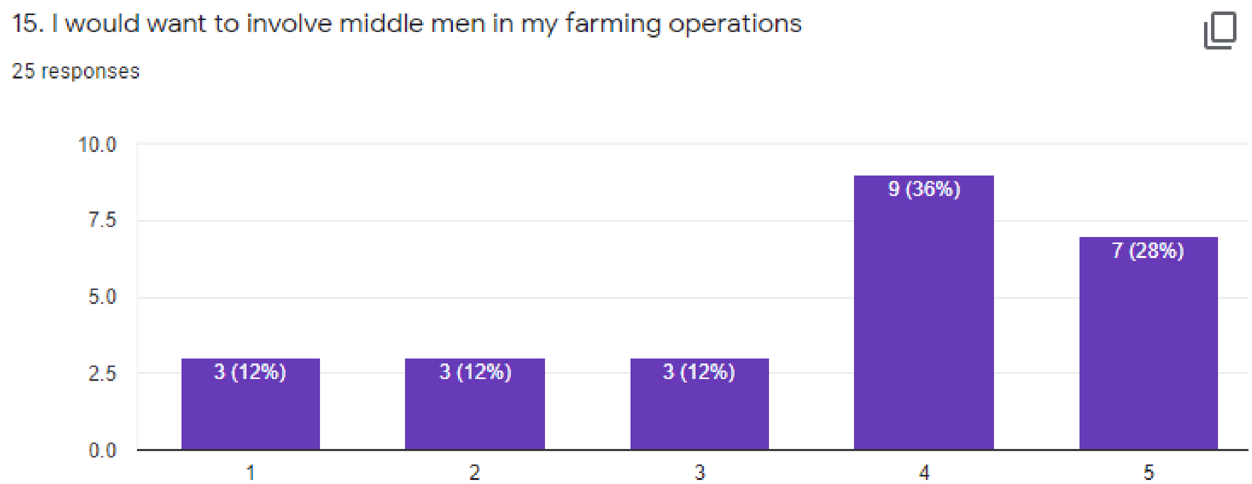

Figure 15:I would want to involve middle men in my farming operations

It was also notable that given the means, farmers needed to test the soil nutrients requirements on their own. This is from their reluctance to employ such important processes despite having knowledge of the existence of the same. Further, the research item ***"16. I would want to test the soil nutrients requirements on my own, given the occasion"***, got immense support by 48 percent respondents. This is described in **Figure 16.**

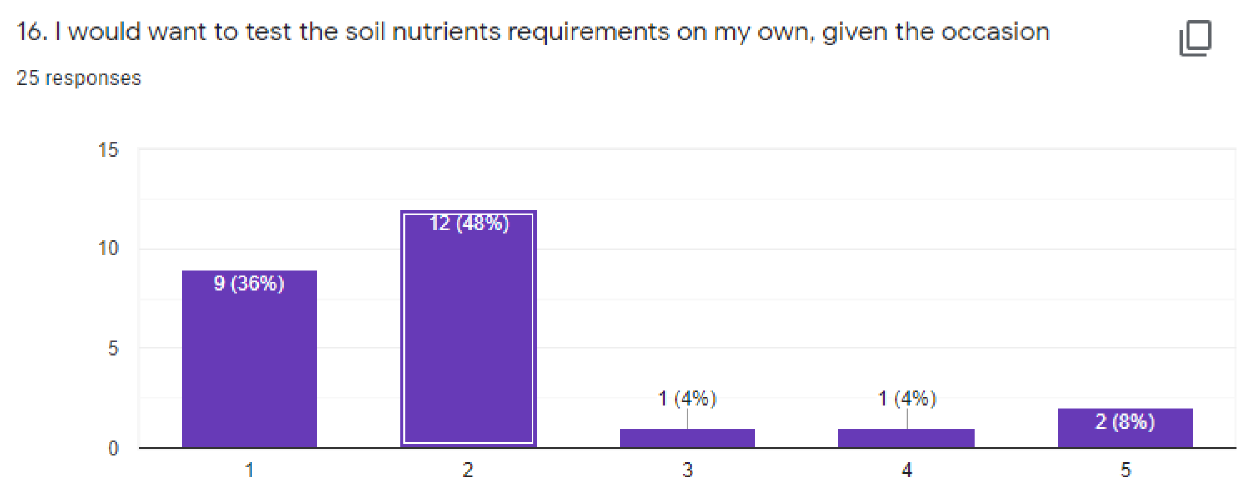

Figure 16:I would want to test the soil nutrients requirements on my own, given the occasion

Technology Proliferation

This is the fourth proposed high-level theme. Augmenting technology with farming appears to have promising outcomes. This is evident from our suggestion to a respondent that through her smart phone she could use applications to identify pests, diseases and products that would control them. This was to ensure the genuineness of supply from the merchants. Applications that showed how to look after her soil and be able to ask for the right fertilizer to apply through soil nutrient status and correct feeding of the crop she was growing, was also introduced. The idea was readily accepted with farther need of information on

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markets through her mobile. In addition, the idea got more support from the respondents' data on the research item ***"17. Given the occasion, I would use technology to enhance my farming operations"***, indicating a high of 48 percent, as shown in **Figure 17.**

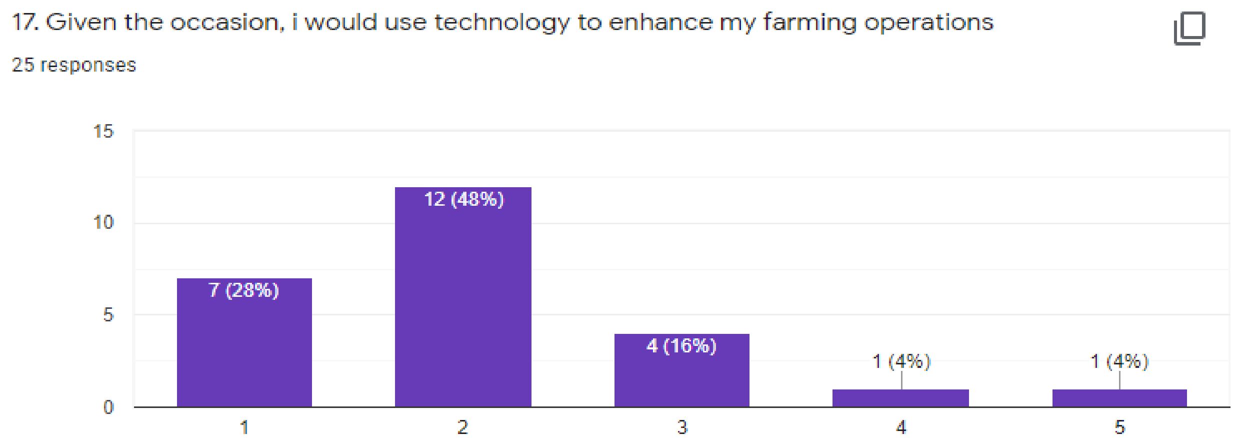

Figure 17:Given the occasion, I would use technology to enhance my farming operations

Other research items ***"18. It is possible to identify pest and diseases using smart phone applications"***, "***19. Mobile apps to advice on the right fertilizer to apply for correct feeding of the crop is important to farming "***and ***"20. Mobile apps to provide real time market information is necessary to farming"*** showed significant support to the conceptual category as shown on **Figures 9, 10** and **11**.

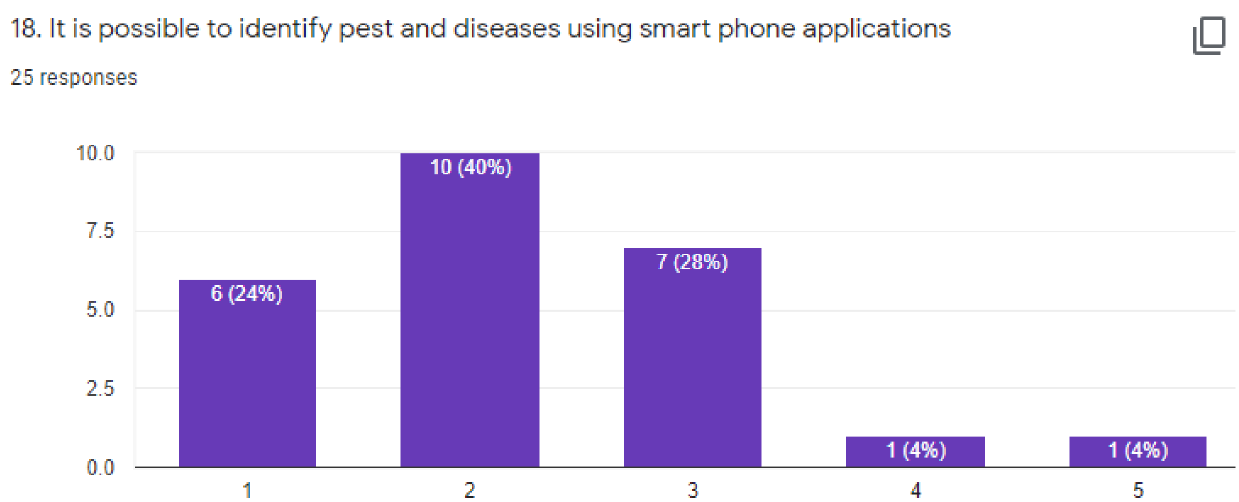

Figure 18:It is possible to identify pest and diseases using smart phone applications

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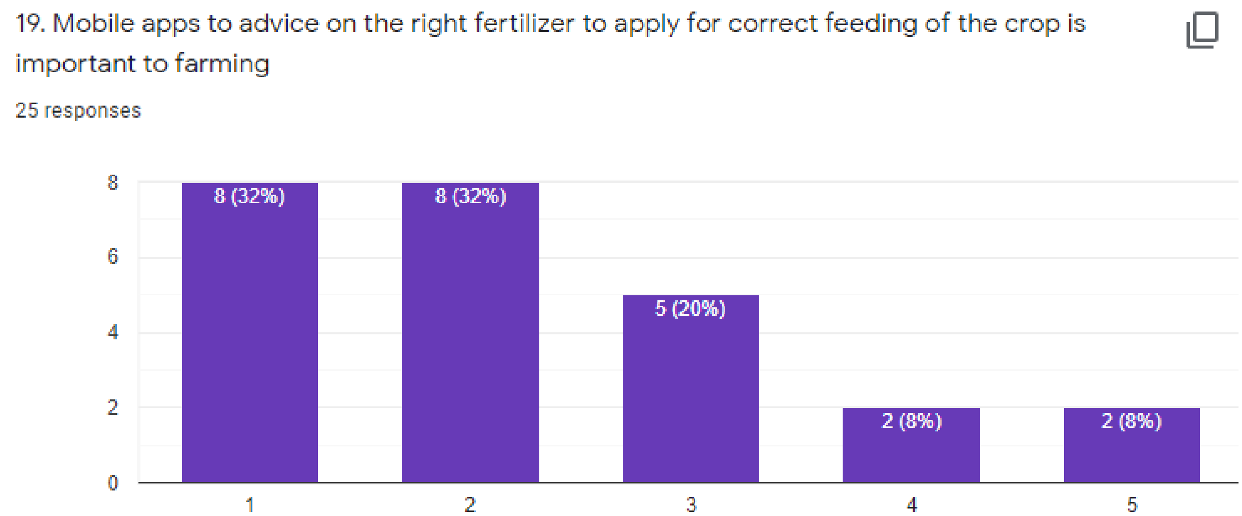

Figure 19:Mobile apps to advice on the right fertilizer to apply for correct feeding of the crop is important to farming

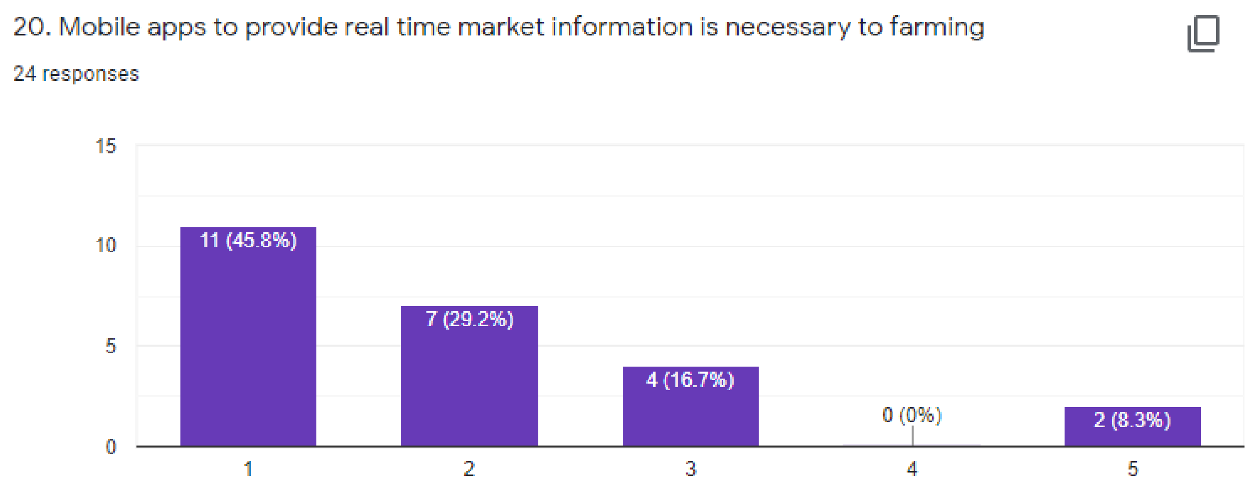

Figure 20:Mobile apps to provide real time market information is necessary to farming

Discussion

From the preliminary findings, it was evident that cooperative Society meetings and fellow farmers were the main source of information on farming. However, these means appeared to change in our second phase of data collection to Internet and mobile Apps. The majority of farmers had either basic phones or smart phones. Soil testing was a rare venture that could only be done by farmers with own means to travel to Naivasha where testing facilities are located. Advise on fertilizer input were got from Merchants or Agricultural Extension Officers who in most cases were not locally available. Potatoes and maize were the main crops though other farmers planted wheat, cabbages and carrots; raising concerns on what informs farmers on the type of crop to plant on each plating season. The cost of inputs is also calculated manually, compromising accuracy and efficiency. Lack of proper soil information and unpredictable change on rainfall pattern is touted to be the cause of waterlogged crops and ruined tubers. Lack of market information and middle men, perceived to be making lots of money are other prominent challenges. In the findings, there was no mention of pest control, meaning that they could be exposed to harmful pesticides that might not have knapsack approval.

In summary, there seems to be an overwhelming lack of soil analysis testing. Therefore, crop nutrient management plans cannot be properly applied. It seems that fertilizer is sold to farmers based on what is available and not what is required for correct plant nutrition. This could be having a significant effect on yields and therefore small holder income. Lack of knowledge on soil types and soil structure could also be affecting soil erosion leading to pollution downstream.

Conclusion

This study has presented a review of literature on the possibility of using grounded methods in developing new theories. Accordingly, high-level themes were proposed which includes: Reliable information source is key to foster precision farming, Farmers' awareness on certified farm inputs Knapsack training kit and soil testing mechanisms can improve crop management and eventual farm yield, Farmers' self-autonomy through elimination of middlemen and the capacity to do soil testing on their own can make them independent and cut on expenses, and The ability of farmers to augment technology in form of using mobile application soil testing, pest and disease identification, identification of genuine seeds, among others can save on cost, increase and promote instant decisions .

Recommendations

As part of our future work, this study will endeavor to establish how the identified themes can be enhanced through further research using the principles of grounded theory. We will also seek to explore on how machine learning algorithms can impact precision farming. In addition, we intend to coin our earlier identified factors into constructs to be used in a model to evaluate use of technology for precision small-scale farming.

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