

A mobile application for recommended fertiliser application rates of selected crops in central Uganda

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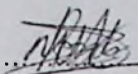
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Declaration

I ROBERT MUTYABA declare with certainty and to the best of my knowledge that this project report is my original work and has not been presented anywhere for an award.

Signature 

Date: 21st / 04 / 2021

Approval

I, the supervisor, have approved this report. It meets the examinations' requirements for the award of a Master of Science in Information Systems Degree of Makerere University

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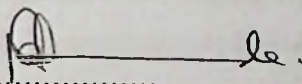
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Acronyms

APK	Application Kit
APP	Application
BIID	Bangladesh Institute of ICT in Development
CAES	College of Agriculture and Environmental Sciences
CM	Centimeter
CMYK	Cyan, Magenta, Yellow and Key (Black)
DAP	Diammonium Phosphate
DB	Data Base
DFD	Data Flow Diagrams
ERD	Entity Relation Diagram
FAT	Functional Acceptance Test
FAO	Food and Agricultural Organization
FOT	Fertiliser Optimizer Tool
FRS	Fertilizer Recommendation Solution
GB	Gigabyte
GDP	Gross Domestic Per capita
GPS	Global Positioning System
HSL	Hue, Saturation, Lightness
ICT	Information and Communication Technology
KGS	Kilograms
LAB	Laboratory
MAAIF	Ministry of Agriculture Animal Industries and Fisheries
MAK STK	Makerere Soil testing Kit
MB	Megabyte
MUZARDI	Mukono Zonal Agricultural Research and Development Institute
MVP	Model Viewer Presenter
N	Nitrogen
N-1	Number minus one (1)
NARL	National Agriculture Research Laboratory
NARO	National Agricultural Research Organization
NPK	Nitrogen Phosphorous and Potassium
OFRA	Optimizer fertiliser rate application system in Africa
OM	Organic Matter
PH	Acidity and Alkalinity
QFD	Quality Function Deployment
RAM	Random Access Memory
RGB	Red, Green and Blue
SA	System Architecture
SD	Standard Deviation
SDLC	System Development Life Cycle
SE	Standard Error
SPSS	Statistical Package for Social Scientists
SRDI	Soil Resource Development Institute

SSA	Sub-Saharan Africa
ST	System Test
UAT	User Acceptance Test
UBOS	Uganda Bureau of Statistics
UI	User Interface
USA	United States of America
UN	United Nations
XML	Extensible Markup Language
XYZ	Red, Green and Blue
YUV	Red, Green and Blue

Abstract

In order for farmers to realize acceptable yields and returns to their scarce resources under these poor soil conditions, they require to use improved soil fertility management practices that they always find unaffordable. Uganda is known as an agricultural country, where most agricultural practice recommendations are given by traditional methods. At present, fertiliser application rates recommendations for farmers are based on one to one communication between the farmers and the experts and these experts have different recommendation rates.

The main objective of this project was to develop a mobile application that analyses soil nutrient's results and provides recommended fertiliser application rates information to farmers after carrying out soil nutrient tests. The project objective was achieved through the use qualitative methodology for requirement gathering and the System Development Life Cycle (SDLC) for the development of the application through the guidance of the waterfall model.

The field results analyzed showed that 80% of the farmers interviewed had been trained on the use soil testing kit (STK) to analyze soil nutrients that helped in requirements identification. They identified color interpretation, no access to the soil testing kits and lack of enough training as some of the reasons as to why they do not carry out soil tests by themselves. From the results analyzed farmers still indicated that they were faced with the following challenges while carrying out soil nutrient analysis; run out soil of reagents, it's a long process, identification of color while others indicated that they had no idea since they had never attained any training. From the analyzed results, 80% of the farmers attained their fertiliser recommendations from extension staff. In addition to that, the commonly tested for soil nutrients were Nitrogen (N), Phosphorous (P), Potassium (K), Alkalinity (PH) and Organic matter. This guided and resulted into the development of the mobile application that interprets, analyzes and provides recommended fertiliser application rates to farmers after carrying out soil analysis.

This mobile application would subsequently aid in improving turnaround time for delivery and attaining of recommended fertiliser application rates by farmers. This smart environmental choice allows growers to save money and increase yields, by using the right rate and type of fertilizers. The solution also addresses the global misuse of fertilizers that results in waste, soil damage, and groundwater contamination. It also enhances fertiliser management through provision of timely information concerning correct timing, placement and methods of fertiliser application and right source of fertiliser in order to maximize nutrient uptake and yield targets.

The mobile application focused on the use of Information Communication Technologies (ICTs) as a tool through which recommended fertiliser application rates can be disseminated to farmers timely and in a cost saving way. This application can be used on farmer's android-based mobile devices. Inorganic fertiliser use has a significant potential production increase in the agricultural sector that in return leads to increased income to the small-scale farmers although farmers are still faced with a challenge of interpreting soil test results and attaining timely onsite recommended fertiliser application rates in order to rejuvenate the soil fertility. It is highly recommended to use the fertiliser application rates mobile application in order to improve on fertiliser application decision making.

Keywords; Android, Nitrogen, Phosphorous, Potassium, Fertilizer Recommendation, Fertiliser recommendation systems

Chapter one

1.0 Introduction

“Ever since humans developed agriculture, we’ve been transforming the planet and throwing the soil’s nutrient cycle out of balance” (Sarah, 2015) and yet the livelihoods of many families in the developing world depend heavily on agriculture and small businesses. Agriculture is the main stay of the African economy where it contributes between 29-58% GDP, 66-100% of export earnings and employs 68-92% of the population (Masuki *et al*, 2010; FAO, 2015). It is therefore the main source of income, employment, food, foreign exchange and it supplies raw materials for domestic industries. Agricultural growth is essential for economic growth and poverty eradication in the continent and very few countries have had rapid growth rates without agricultural growth preceding or accompanying it (Agriculture in Uganda, 2001). In East Africa, all the countries can be characterized as “agriculture-based countries,” that is, agriculture is the backbone of these economies (Salami *et al.*, 2010).

The United Nations Food and Agricultural Organization estimates that 60% of the world’s population depends on agriculture for survival (FAO, 2015, Rattan Lal 2015). Over 80% of Uganda’s households (and 85% of the people) live in rural areas, and most of these depend on agriculture as their primary source of income (Hartter, J, 2015; Jackline, B, *et al* 2015). Government estimates that in some regions of the country, 85-90% of the households receive their main source of income from subsistence agriculture (Douglas *et al.*, 2010; Harter, J, 2015; Jackline, B, *et al* 2015). The sector contributed 24.9% of the national Gross Domestic Product (GDP) and 72.9% of the total national export earnings (MAAIF, 2016, UBOS, 2017). There is fear that this contribution may reduce due to declining productivity as a result of land degradation, limited knowledge on the soil nutrient levels and the quantity and quality of fertilisers required for crop production (FAO, 2017). Farmers apply inadequate proportions of fertilisers, which lead to poor harvests.

Smallholder farmers need to access information about new technologies before they can consider adopting them and thus look up to agricultural researchers and extension agents as sources of new technologies. Makerere University is currently addressing soil nutrient analysis through distribution of soil test kits to the local community with the help of extension staff. The kits give information on soil nutrient levels but do not give recommendations on fertiliser application rates. With this, there is a need to help farmers get timely recommended fertiliser application rates that are needed to rejuvenate their agricultural land through the use of a mobile application hence increasing on crop production.

1.2 Problem statement

Despite the fact that farmers have been trained on how to carry out soil nutrient analysis using the Makerere soil testing kits in a bid to address the soil nutrient problem in most parts of the country, they are still faced with the challenge of interpreting the soil nutrient test results in order to determine the recommended fertiliser application rates which calls for experts (extension staff) intervention. However, this traditional approach of providing agricultural information through extension services is overstretched, time consuming and under-resourced. With this, a mobile application can be used to accurately analyze and enhance the delivery of timely onsite fertiliser application rate recommendations to farmers after carrying out soil nutrient tests. A couple of native and web based fertiliser recommendation application systems have been developed; “Mrittika” in Bangladesh, SMART fertiliser management system in USA, N’ Advisor in Austria, Optimizer fertiliser rate application system in Africa (OFRA) and others but these do not give enough solution to the farmer’s problem in that most of the application systems capitalize more on the money the farmer has available to invest in fertiliser, some deliver fertiliser recommendation based on the fertilisers already available in their stock and others use extensively generalized soil analysis which biases the minimum fertiliser application rate that a farmer would use. So coming up with a native mobile application would help to solve this problem.

1.3 Objective

To develop a mobile application that analyzes soil nutrient results and provides recommended fertiliser application rates information to farmers after carrying out a soil nutrient test on their land.

1.4 Specific objectives

- i. To establish the requirements needed to develop a mobile application in order to enhance the dissemination of recommended fertiliser application rates information (Information and system requirements).
- ii. To design the mobile application’s processes, functions and structure in order to get an insight of the application before development.
- iii. To implement the mobile application basing on the design generated.
- iv. To validate the mobile application. The mobile application will be validated to ensure that it delivers timely fertiliser recommended application rates to farmers.

1.5 Scope

The tool was limited to a mobile application because of the cost, complexity and time constraints. The tool based on the Makerere soil testing kit because of its availability in the farming community.

The research was conducted in the central part of the country mainly Wakiso and Mukono Districts. The criterion for selection of these Districts was because these Districts grew much of the identified crops, proximity of the researcher to these places and the financial constraint to conduct the research.

The tool concentrated on maize and beans as the main crops because of their high consumption and being widely grown in the area of study.

The application developed based on the annual crops fertiliser recommendation manual guide developed by National Agricultural Research Laboratory (NARL) in Uganda.

It involved farmers, extension staff, soil scientists and information technology experts.

1.6 Justification

The application system enabled interpretation and analysis of soil nutrient results and provided timely on site recommended fertilizer application rates to farmers since it had been a major challenge. With the presence of this application, there is a reduction in farm cost since the aspect of extension staff worker is no more hence increase on farm output. The application-equipped farmers with knowledge on where to attain the necessary fertilisers and their unit costs hence a voiding manipulation by intermediaries. With this application, the issue of blanket cover recommendation was reduced which in turn addressed the global misuse of fertiliser that results in waste, soil damage, and groundwater contamination.

Chapter Two

2.0 Literature Review

Introduction

An in-depth review of literature concerning soil nutrition depletion (in Africa, East Africa and Uganda), fertiliser use in sub-Saharan Africa and Uganda, current methods of soil analysis and fertility, mobile phone usage in agro service delivery, color image processing tools and technics, related fertiliser recommendation systems in place and limitations of existing fertiliser recommendation systems. This was to get a clear understanding of the soil nutrient status, fertiliser use, agro service delivery mechanisms and implementation of the mobile application based on the available fertiliser application systems. This in turn would highlight the relevance of this project in the context of Ugandan farmers.

2.1 Soil nutrient depletion

Our soil is losing its ability to perform the services that are essential for humans to survive. The Nitrogen, Phosphorous and Potassium (NPK) values of the soil determine the quality of soil. Testing of the soil based on these can help in recommending of fertilisers that need to be added to the soil to increase the crop yield (Joyce. G. *et al*, 2015). Over exploitation has diminished soil's capacity to retain water and nutrients, produce food and absorb carbon dioxide, according to the Global Opportunity Report of 2017(Global Opportunity Report of 2017). The UN Food and Agriculture Organization (FAO) estimates that food production must increase by 70% between now and 2050, if we are to feed the growing world population (FAO 2016).

According to the International Center for Soil Fertility and Agricultural Development, there is substantial soil decline in every major region of Sub-Saharan Africa and the highest rates of depletion being in Uganda, Guinea, Congo, Angola, Rwanda and Burundi (Uganda Radio Network, 2006). A study carried out by Bationo *et al* indicated that the average nutrient loss for South Saharan Africa was as follows: 1982-1983: 22 kg N, 2.5 kg P and 15 kg K; 2000: 26 kg N, 3 kg P and 19 kg K. This indicated persistent nutrient mining over time (Bationo *et al.*, 2012). It is estimated that annual nutrient depletion in Uganda stands at an average of 87 kgs of nutrients (NPK) per hectare per year (38 kgs of Nitrogen; 17 kgs of Phosphorous and 32 kgs of Potassium) (Fertiliser use and fertiliser consumption by crops in Uganda, 2015), making it one of the highest rates of soil nutrient depletion in Sub-Saharan Africa (SSA). Moreover, the cost of replenishing the depleted soil nutrients is high, averaging roughly 20% of household income (Nkonya *et al.* 2005, Diiro *et al* 2015). With this high level of soil depletion in Uganda, was one of the biggest motivational factors that geared up the study to develop a mobile application that can analyze soil and provide timely fertiliser recommendations to farmers hence making it easy for farmers to access fertiliser recommendations to replenish the farm land which will transform into improved nutrient levels and better crop yields.

2.2 Fertiliser use in Sub Saharan Africa (SSA) and Uganda

It has been observed that the overall use of inorganic fertilisers in South Saharan Africa is just twelve (12) kgs per hectare (ha) the lowest in the world. Use of fertiliser in the region involves

average applications of less than nine (9) kgs of Nitrogen and six (6) kgs of Phosphorus per ha, compared with typical crop requirements of 60 kgs of Nitrogen and 30kgs of Phosphorus per ha. (Swift *et al* 2007; FAO 2015). Results from field trials conducted by Sasakawa Global 2000 show that the application of fertiliser (at a rate of 90:40 kgs per hectare of Nitrogen and Phosphorus) to maize yields 4,312 to 6,054 kgs per hectare compared to the 550 kgs per hectare for farmers who do not use fertilisers. Despite these proven beneficial effects of fertilisers, its use in SSA countries continues to lag far behind other developing countries (Diirro *et al* 2015). In Uganda in particular, both the fraction of farmers using fertiliser and the intensity of fertiliser application are quite low. A major domestic constraint is poor knowledge at farm level on the benefits of fertiliser and agronomic practices required to achieve high productivity, which has led to low adoption rates (Uganda Fertilizer Assessment, 2014). Yamano *et al* (2010) found that only 7 to 8% of Ugandan farmers used fertilisers in 2009, compared to about 17 to 31% reported by Suri (2011) in neighboring Kenya. In addition, an average farmer in Uganda applies about 2.1kgs per hectare, far below the 32.4 kg per hectare used by a farmer in Kenya (World Bank 2013, Diirro *et al* 2015).

Several explanations for low fertiliser use have been advanced by economists Benson *et al.* (2013) who suggest that farmers are uncertain of the returns from fertiliser due to price volatility and other source of risk, such as pests and diseases whose joint distribution with fertiliser is unknown. Kelly (2006) and Morris *et al.* (2007) suggested that farmers lacked adequate knowledge and skills in using fertilisers. Yamano *et al.* (2010) reported that literacy and agricultural extension increase fertiliser adoption because they enhance a farmer's technological awareness. According to Okoboi *et al.* (2012), they found out that farmers in Uganda do not use fertilisers primarily because of lack of liquidity and knowledge of the use of fertilisers. And yet fertilisers are a crucial input driving global food production. There is a clear correlation between increased production and use of fertilisers. So choosing the correct fertiliser formula requires precise data analysis, not trial and error. The fertiliser application systems are based on extensive research and exact chemical calculations not usually available to growers.

Based on the fertiliser usage statistics, they show that Uganda is amongst the least users of fertilisers at 2.1kg per hectare (World Bank 2013, Diirro *et al* 2015), it clearly comes out that farmers don't have enough capital to invest in fertilizers which calls for an external intervention to see that a solution is crafted in order to enhance fertiliser usage. With this, coming up with a tool that can reduce on the production costs such as; on extension staff, extra fertilisers bought, cost on getting available fertiliser suppliers and lost time while travelling to the research LABs for soil analysis was vital. This triggered the study to develop a mobile application that can enable farmers get the right fertiliser recommendations readily for their fields, know where to get the fertilisers and also reduce on the time that is used to get the recommendation to less than an hour hence encouraging farmers to use fertilisers. It was also noted that farmers needed expert intervention on fertiliser use and fertiliser application recommendation rates which is not enough physically but through such an application, farmers can be reached out which boosted the researcher's study.

2.3 Current methods of soil analysis and fertility

To evaluate the soil fertility status in East Africa (EA.) and Uganda in particular, farmers and agronomists are using realistic indicators namely; crop yield levels, chemical analysis, limiting

nutrients and nutrient balances data that have been collected in the region over time. Presently, fertiliser rates recommendations for farmers are based on one to one interaction between farmers and the experts and different experts have different recommendations (Praveen.S. *et al* 2013; Nilkamal. M *et al*, 2014). The agricultural extension staff carries out soil nutrient analysis using the soil testing kit and gives recommendations based on attained soil nutrient results. The recommendations are based on the generalized soil fertiliser recommendation literature and manuals that are provided by the Food and Agriculture Organization (FAO), the National Agricultural Research Laboratory (NARL) and other fertiliser recommendation manuals. With the advancement in technologies, ICT especially mobile phone technology can be used to enhance on soil nutrient analysis and timely accessibility of recommended fertiliser application rates after carrying out actual nutrient tests by farmers. It's upon this advancement in technology that geared up the idea (study) to come up with an application that can enable farmers to easily interpret and analyze soil nutrient levels using a recommended scientific method and also bring together the available fertiliser recommendations from experts and Institutions into a unified tool for easy access by any intended user. So through a mobile application the aspect of using realistic indicators for soil fertility analysis could be improved upon for better results (reduction in fertiliser wasting). This in addition motivated the study to get a solution that can improve on identified challenges.

2.4 Mobile phone usage in agro service delivery

Over the past few years, there has been a remarkable progress in the use of ICT's in agriculture, especially in the area of farmers' access to agro-services delivery. Various projects have been developed that integrate ICTs into the dissemination of agricultural information to farmers (Uddin, Md. J, *et al* 2013). ICT means information and communication technology which is an umbrella that includes any communication device or application, encompassing; radio, television, cellular phones, computer and network hardware and software, satellite systems and so on. In these aspects, the term Information and Communication Technology (ICT) has come in the sight to the advisory services of farmers safeguarding the environment in a cost effective way (Uddin, Md. J, *et al* 2013).

In a study carried out in Zimbabwe, it was found out that ICTs in particularly mobile applications were effective in the dissemination of agricultural information (Tinashe.M. *et al*, 2015). The rate of growth of mobile phone technology is particularly striking. Mobile phones are helping farmers link to one another and obtain early information from markets (Drake *et al.*, 2017). Smartphone ownership rates in emerging and developing nations are rising at an extraordinary rate, climbing from a medium of 21% in 2013 to 37% 2015 (Ali.N. *et al*. 2010). There was an increase of telephone subscribers from 23.206 million subscribers in 2016 to 23.211 million subscribers in 2017 in Uganda (UBOS statistics 2019).

According to the baseline survey that was conducted by Mercy corps in 2013, there appeared to be a great deal of potential for reaching smallholder farmers in all the three countries (Uganda, Zimbabwe and Indonesia) because the majority of the surveyed households had access to at least one mobile phone and own at least one active SIM card. In Uganda, 65% of the farmers have a mobile phone with 90% of the households having access to a mobile phone. In addition, according to the slow food network in Uganda, 75% of farmers in Uganda can access the mobile phone based extension services (Slow food, 2017).

Currently, knowledge and innovation are now widely regarded as key drivers of economic growth and it is clear that information and communication technologies (ICTs) are deeply implicated in knowledge flow and innovation (Verlaeten, 2002; Masuki *et al*, 2010). It's upon this growth in mobile phone usage that advantage can be taken up to analyze and disseminate timely on site recommended fertiliser application rates to small holder farmers easily in Uganda.

2.5 Color image processing tools and techniques

Colour is often the only characteristic that can be used to differentiate clearly between two otherwise completely similar objects. When it comes to the recognition of colour, the human eye can recognise not even one hundred (100) grey values and only approximately seven (7) million different colours (vision online.org). The typical task for a colour sensor camera is to inspect the object according to its colour. With a colour sensor such as the Eye Check 2000 C, it is possible to solve colour evaluation applications such as the inspection of colour sequence and quality of multi-core cables or the sorting of test tubes in the pharmaceutical industry. Background removal and color segmentation are some of the color identification methods used.

According to Ladislav. B. *et al* (2014), Image segmentation is the process of dividing pixels in an image into categories based on shared visual characteristics like a shared edge, colour, texture etc. The segmentation process is based on the GrabCut segmentation technique, which is considered as one of the powerful state-of-the-art techniques for the problem of color image segmentation (Rother. C *et al*, 2004). Such problems may correspond to individual surfaces, objects, or natural parts of objects. Furthermore, it can be defined as the process of labeling every pixel in an image, where all pixels having the same label share certain visual characteristics (Lalitha. M *et al*, 2013).

Segmentation aims to divide an image into regions that can be more representative and easier to analyze. The automatic GrabCut utilizes the unsupervised Orchard and Bouman clustering technique for the initialization phase. Automatic GrabCut is applied with RGB, HSV, CMY, XYZ, YUV and color spaces. The comparative study and experimental results using different color images show that color space (organization of colors) is the best color space representation for the set of the images used. The image segmentation is an important first step in object detection.

The most widely used color space is the RGB color space, where a color point in the space is characterized by three color components of the corresponding pixel which are red (R), green (G) and blue (B). Image segmentation is simply the process of separating an image into foreground and background parts

Based on a comparative study between the RGB and HSV models, Ruiz-Ruiz *et al* (2009) declared that the best accuracy was achieved with representation in order to achieve real time processing in real farm fields for crop segmentation. With this, the researcher saw this as an opportunity to use image segmentation tools that have the RGB and HSV models to solve the color identify color.

2.6 Related fertiliser application systems

Developments on fertiliser application guidelines have been done to provide farmers for fertiliser application decision making, though they are mostly blanket recommendations are infeasible for small holder farmers with limited financial resources. In Bangladesh, a joint venture between Grameen Intel Social Business Ltd and eKutir Social Business enterprise based in Orissa, India to guide on fertiliser application through the use of 'Mrityika'. It is a soil nutrient analysis and recommendation tool that enables farmers to receive input requirements for their fields. Rural entrepreneurs offer soil testing services to farmers and use *Mrityika* to analyze the results to recommend the farmers on the selection of crop for achieving cost effective and optimum productivity (BroTecs, 2013). Based on crop, soils, land condition, cropping season, *Mrityika* recommends specific fertiliser application amounts. *Mrityika* also tells farmers where they can purchase the required fertiliser, the cost per kilogram and the total cost for the amount of fertiliser recommended. The report includes information on the soil pH, organic carbon, and other key chemical levels as the fertiliser requirements for their plot split out by fertiliser type and quantity. Also was the Fertilizer Recommendation Solution (FRS) *e-Krishok* which was developed in Bangladesh by Soil Resource Development Institute (SRDI), with support from Katalina (a development project) and promoted by Bangladesh Institute of ICT in Development (a service of the *e-Krishok* program (New Agriculturist, 2012). The FRS system is a solution to guide the farmers on correct doses and types of fertilizer for the specific local crop (Uddin, Md. J, et al 2013)

SMART Fertilizer Management system is a decision support platform for optimizing fertilizer use for agriculture, enabling growers to maximize crop yields, save costs and increase profits. It was founded in 2008 by Guy Sela, an agronomist specializing in irrigation and nutrition in the United States of America (USA). The platform supports over 250 different crops in a wide range of geography. SMART software has been field-tested in over 350 different agricultural sites in 46 countries and on dozens of crops. The tool is being used to create fertiliser plans and recommendations, soil testing for nutrients, evaluate irrigation water, interpreting tissue test results and optimize fertiliser use. Growers simply enter information on water quality, soil composition, irrigation system specifications and crop data and it returns an individualized formula with optimal recommendations. If fertigation is used, fertiliser recommendation is followed by a schedule for distribution into fertiliser stock and application. SMART Fertiliser Management Software delivers highly-accurate fertiliser programs using the fertilizers already available in your stock. (<https://www.smart-ferti.com>)

In Austria, a web-based application called the 'Dairy Nitrogen Fertiliser Advisor (N-Advisor)' was developed. This application was intended to give marginal analysis and maximizing principles to assist dairy farmers and their advisors when they are considering how much N to apply to a particular paddock for a particular grazing rotation. The tool uses rigorously defined response functions for pasture dry matter consumption that can be derived from the range of possible applications of N. Nitrogen fertiliser recommendations are based on using the N-Advisor incorporate the marginal product derived from the calibrated response function, the costs of the fertiliser (as applied) and the value of the extra pasture consumed.

aim of the N-advisor is to provide production and profitability information that has the rigour and relevance to add value to farmer decision-making about their application of N (Scott *et al*, 2016). The N-Advisor takes into account the same factors as the current decision making approaches: i.e. the pasture response to additional N, the 'as spread' cost of N fertiliser, and the opportunity cost of pasture consumed as represented by the cost of bought-in substitutes.

The Optimizing Fertiliser Recommendations in Africa (OFRA) was a project funded to find strategies to enable resource poor farmers to get the best returns from their small investments in fertiliser. In Uganda, a Fertiliser Optimization Tool (FOT) was developed to help farmers make decisions on the most profitable crop-nutrient combination so as to get maximum returns. It considers the area of each crop, fertiliser costs, expected grain value, and the money available for investment. The recommendations are based on extensive research into fertiliser response functions taken from new field trials undertaken by the National Agricultural Research Organization (NARO) and further data drawn from legacy research. The optimizer tool is an innovation that considers the money the farmer has available to invest in fertiliser (Harrison Rware *et al*, 2016). So such universal systems have been intended to assist farmers in agriculture production though they don't fully offer solution to farmer's problems. Data mining techniques and algorithms can be used for recommending crops and also the use of fertilisers (Mansi S. *et al* 2016). This kind of system can help development of various algorithms which can be used in building an efficient recommendation system. The system which recommends the right fertiliser application rate to the farmers thereby increasing their crop production.

Though many soil sciences related Institutes, Universities and fertiliser producer companies have developed their own recommendation (Zorn. W. *et al* 2007; Nandor.F. 2011). Systems developed by fertiliser companies tend to recommend higher doses than those developed by 'disinterested' research institutes. Practically each recommendation system is based on simple nutrient balance equations, though the elements of the input and output sides could be calculated using quite different methods. One possible way is to use sophisticated dynamic models while the generally used method is to utilize correlations that were established based on a database of long-term fertiliser experiments. Sometimes it is not only scientific principles, but business interests or even political deliberations are also incorporated into certain advisory systems (Nandor .F. 2011). For example the MÉM-NAK fertiliser recommendation system was identified unfit to help the Hungarian farmers in their fertilizing practice. The major fertiliser recommendation systems are also sensitive to the reliability of the input data for precise estimation of fertiliser rates and compromises such as maintaining large field sizes and skipping leaf analysis of some fields should not be made except when they are sure. Therefore, we should not rely on ad-hoc methods to draw up the fertiliser rates or provide the same fertiliser rates to crops on very different environments. With that, the development of a new cost-saving and environment-friendly fertiliser recommendation application cannot go unnoticed here in Uganda.

Ng SiewKee (1977) stated that "The continuing pressure of high fertiliser prices since the "energy crisis" have demanded a critical search for possible measures to economize on and maximize benefits from fertiliser inputs. The past attitude of a large insurance margin in manuring because of relatively cheap supplies is no longer tenable." (Goh, K.J.). The phrase implies the necessity of a system of working out the optimum fertiliser rates correctly, which forms the main purpose of this research. So with the development of this application system, it

will be very essential for the agronomists who need to use an objective and scientific fertiliser recommendation system which is capable of computing the optimal fertiliser rates that are repeatable for their conditions and do not vary substantially between them.

2.7 Limitations of existing fertiliser application systems

It has been observed that most of the fertiliser rate application systems capitalize more on the investment or money the farmer has available to invest in fertiliser which biases the minimum fertiliser application rate that a farmer would use (for example OFRA and FOT).

Some fertiliser management systems deliver fertiliser recommendation using the fertilisers already available in your stock (for example SMART).

Most of the recommendations provided by the existing systems are based on extensively generalized soil analysis carried out in the region or agro-ecological zone which may not give the actual right rates needed on the farmer field hence misuse of the fertilisers available.

It has been noted that systems developed by fertiliser companies tend to recommend higher doses than those developed by 'disinterested' research institutes. So which implies that sometimes it is not only scientific principles but business interests or even political deliberations are also incorporated into certain advisory systems for example the "MÉM-NAK" fertilizer recommendation system.

Most of the available systems are computer based which do not offer the flexibility required.

2.8 Conclusion

Attempts to provide farmers with recommended fertiliser application rates have been done and some fertiliser recommendation application systems like Mritika, SMART fertiliser management system, N' Advisor, Optimizer fertiliser rate application system (OFRA) and others have been developed though these systems have their own challenges as seen the constraints section 2.7 above. And so these systems have ended up not giving enough solution to the farmer's problem. The development of a native mobile application comes in handy to help farmers to interpret, analyze soil nutrients and also provide timely lowest possible fertiliser recommendation rates required to achieve high yields. Notably, the principle is not to have the highest possible yield but to reach the maximum income per unit area while allowing minimal agricultural NPK losses to surface and subsurface waters. Also to note is that with the present knowledge of soil nutrition, the mobile application will allow the production of site-specific fertiliser recommendations. The other benefits in the system will include fertiliser management practices which will include correct timing, placement and methods of fertiliser application and right source and prices of fertilisers recommended for optimum growing conditions. This mobile application will offer a solution to the site specific recommended fertiliser application rates information and also reduce on fertiliser use knowledge gap in the agricultural sector hence increased production.

Chapter Three

3.0 Methodology

Introduction

This chapter presents the research methodology, as well as the techniques and tools that were used in gathering information, requirements and knowledge that was key in enabling the research achieve the research objectives.

3.1 Research Methodology

A qualitative approach (case study and document analysis) was used to gather data relevant for the research (requirements) in combination with the System development Life Cycle process for the development of the application system.

According to Zainal (2018), case study is defined as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and content are not clearly evident; and in which multiple sources of evidence are used”. Case study was most suited for this study because it offers an opportunity for the researcher to participate in the actual analysis of soil nutrient levels process and get the experience of attaining timely recommended fertiliser application rates. Zainal (2018) goes ahead to describe three categories of case studies i.e. exploratory, descriptive and explanatory. Focus for this research was centered on the descriptive category which is defined as a “set to describe the natural phenomena within the data in question e.g. what soil nutrients do you test for during analysis”. Zucker (2018) explains that in a case study, method and analysis go hand in hand making it an iterative process. Document analysis is a form of qualitative research in which documents are interpreted by the researcher to give voice and meaning around an assessment topic (Bowen, 2009).

According to Pedro, (2015) the System Development Life Cycle (SDLC) is a process that starts with the emergence of an idea, goes through its implementation, and ends with its termination, moving across all the intermediate stages in which its viability and usability are prioritized. Basing on the available literature, there is clear evidence that shows that this kind of application could be developed through the guidance of the System Development Life Cycle (SDLC) which was taken on by the researcher. Ragunath (2010), states that a system application cycle deals with various parts and phases from planning to testing and deploying application. All these activities are carried out in different ways, as per the needs.

It was upon this background that the researcher took on these methodologies (qualitative approach and SDLC) to aid in offering guidance to model the business process hence identifying requirements. Then proceed to design, develop and test the tool to ensure it satisfied the requirements specified and ensure the project objectives were successfully achieved. Therefore, the qualitative approach offered a detailed description of the application process using the interviews, document reviews and observations methods (Georgia Department of Education,

2018). It enabled the researcher understand the experience and process by focusing on the Makerere Soil Testing Kit (MAK STK) for soil nutrient level analysis.

3.1.1 The System Development Life Cycle (SDLC)

The System Development Life Cycle (SDLC) process was followed for the development of the mobile fertiliser recommendation rates application due to its ability to provide a step by step procedure for the delivery and implementation of a good quality system. “The Systems Development Lifecycle (SDLC) is perceived as the timeframe that spans from the development of a new system to its eventual retirement” Pedro et al (2015).

In this process, the water fall model was used since it provides a linear way of application development which provides emphasis on collecting requirements, designing the application architecture before development and testing which was highly needed in the development of this kind of application. According to Mith, (2018), this model consists of completing a stage then moving on to the next stage. The Model is simple, methodical, and easy to understand and to implement. It works well and yields the correct results. It ensures quality and identifies deliverables and milestones.

“The major advantage of the Waterfall Model for the SDLC is that it provides a structure for organizing and controlling a software development project. The single most important methodological need in this approach, however, is to identify user requirements accurately.” (Andrew P. et al 1990). With this, the researcher found it appropriate to use this approach in order to have the application system developed accurately through its guidance basing on it advantages and nature of application system.

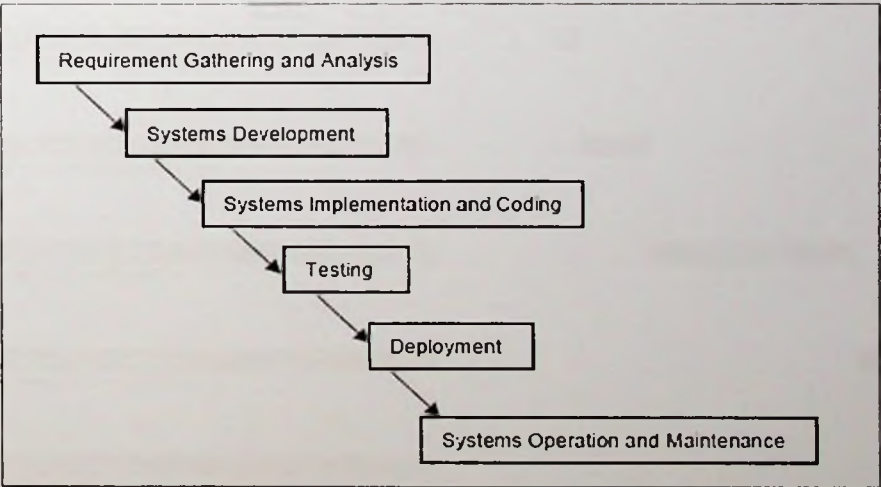


Figure 1: The waterfall model illustration by Mith, (2018)

The approach model included the following stages;

i. Investigation and planning

At this stage the identified problem was researched upon in depth to see that the problem really existed and a solution needed to be crafted.

During the investigation process, Interviews were conducted as a way of attaining in depth information and individual views about the problem that was being faced (see **appendix1; Interview guide**). Some farmers were identified and interviewed in detail on the challenges they faced while analyzing soil nutrients and getting the right fertiliser recommendations rates for their fields. The interview approach was used because it allows interaction and acquisition of broader knowledge about the given subject matter. According to Hamza, (2014), Interviews are more powerful in eliciting narrative data that allows researchers to investigate people's views in greater depth. In a similar vein, Cohen et al (2007) adds that interviewing is “a valuable method for exploring the construction and negotiation of meanings in a natural setting”.

Also at this stage, planning of the project activities was done. The time frame for coming up with the solution was scheduled by use of a Gantt chart. This had the activities for application system development and the estimated time for achievement of each. The budget and cost implications of the project activities were drawn (**appendix 4; Project Budget**). All these were achieved through the use of project manager tool since it provides ways of analyzing project activities in a much detailed format. And by the nature of this project, the researcher needed to critically work on schedule management in order to have the project completed on time.

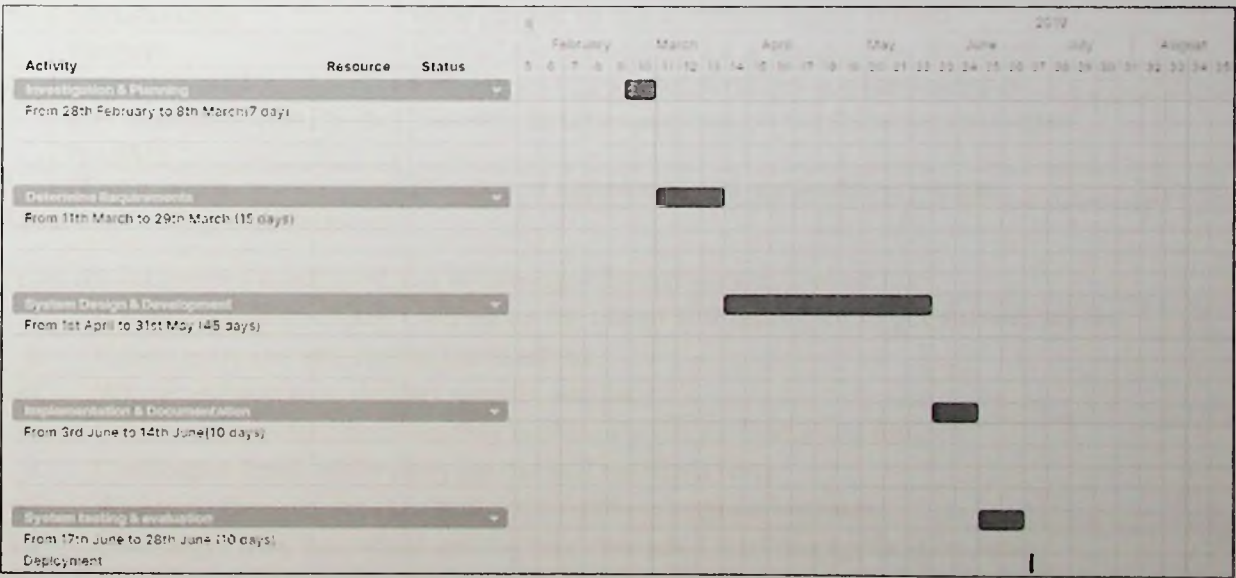


Figure 2: Showing the project activities schedule that was followed throughout the project life; Gantt chart (developed using Tom’s planner project management tool)

ii. Determine requirements

The information and system requirements were identified. The system's functional and performance requirements were identified; the formats of inputs, outputs, any required standards, language to be used, security and economic environments.

According to Buyukozkan (2004), requirement determination plays a significant role in the product development process, especially in the early design stage. Quality function deployment (QFD), as a useful tool in product development provides a systematic approach towards satisfying user requirements. Through the waterfall model, the requirements were transformed into the design and developed the application. Basing on empirical evidence from literature as discussed in the above subsections (3.1), coming up with this kind of application needed requirements information to be done so as to enable the researcher develop an application that is problem solving and relevant to the intended users.

Information requirements

The functional and performance requirements were identified through interviews that were held with selected farmers to find out what the application should do in order to solve the existing problem. The researcher used the interview method of Information acquisition because it offered a faster way to acquire information compared to the questionnaires and others (see appendix 2; Interview guide).

The following stakeholders/ domain experts were involved during the research

No	Stakeholders	Role played in the fertiliser usage system
1	Farmers	User of the soil testing kit & users of the fertilisers
2	Extension staff	Provide recommended fertiliser application rates
3	Soil scientists (CAES & NARO)	Develop fertiliser application combinations and rates
4	IT specialists	Developed algorithms and application systems

Table 1: Showing stakeholders

From the interviews conducted, the following information was looked for;

- i. If they ever attained any training on the use of soil testing kit to get nutrient levels
- ii. If they carry out soil testing themselves
- iii. Which soil nutrients do they usually test for?
- iv. Which mineral fertilisers do they commonly use on beans and maize?
- v. Challenges faced while carrying out soil nutrients tests
- vi. Where do they get the recommended fertiliser application rates
- vii. Challenges they face while getting recommended fertiliser application rates
- viii. The kind of information they would want a mobile application to provide to them concerning soil fertility
- ix. How the soil testing process could be improved upon

Sampling methods

A selected number of farmers were identified for the requirement clarity and testing purposes. Here judgmental or purposive sampling method was used because the participants were selected solely on the basis of research requirements. And here farmers who had been trained on the use of the Makerere soil test kits were selected. The researcher used a small number for easy of management and due to financial constraints to manage a bigger number. (See appendix 3; profiles and roles of stakeholders involved)

System requirements

The structure formats of inputs, out puts, the required standards, language to be used; security and economic environments were determined by analyzing procedures and review documents (literature) of similar applications developed. According to Bowen, (2009), document analysis is a form of qualitative research in which documents are interpreted by the researcher to give voice and meaning around an assessment topic.

By use of this, it helped the researcher to find out more details about the current systems and organization where these systems supported, the problems with existing systems and the opportunities the researcher could use to meet new needs of the farmers.

Some input data observed from similar applications

- i. Farmer details; Farmer name, contact, Location
- ii. Land; land location, land size (hectares), land description
- iii. Harvest details; season (rainy or dry), Irrigation type (rainfall feed or irrigated)
- iv. Crop: maize, beans (locally grown crops)

Soil test (Yes/NO)

Soil parameters levels tested for; PH, Nitrogen, Phosphorus, Potassium, Organic carbon, Magnesium, Calcium and Sulphur

Some output information observed from similar applications

Recommendations

Dosage; Fertiliser recommendation rates given. The quantities or units given in kilograms per fertiliser to be applied.

Summary; Summary of the suggested fertilizers' available supplier, there name, contact and address, they also give the unit quantity of the fertiliser package

Soil report; the soil parameters are indicated with their findings then the recommended quantity of fertiliser to be applied.

System Requirements of similar applications obtained from literature

Hardware & software

The applications operated on mobile devices having screen sizes of at least 7 inches for easy navigation, RAM of at least 512Mb, storage space of at least 2GB.

The applications were supported by most of the mobile operating systems (Android, Windows) and most web browsers (Google chrome, Mozilla, Internet explorer, Opera and others).

For this case, the researcher developed a native application using Android studio software due to its robustness and ability to have many advanced development functions.

Prototyping method was also used by the researcher to determine requirements because prototyping allows the system developers to quickly show users the basic requirements into a working version of the desired information system or application. And according to the nature of the users, this method was appropriate. A prototype of the application system analyzing the soil PH was developed. In reference to Gerhard H, et al (2017), a prototype could range anywhere from post-it notes on a board to a tangible product. The more realistic the prototype is to what an actual user is going to use, the better the feedback and insights for improvement. Prototypes allow teams to recognize flaws in their design thinking progress while having the freedom to iterate their product. This helped the researcher meet specific objective two of his research work. And here Adobe XD application was used by the researcher to develop the prototype (Mock ups).

Requirement structuring

In this section, the researcher focused on the method that would be used to represent the requirements. The Data Flow Diagrams (DFD) was used. DFD is a graphical tool that allows analysts and users to depict the flow of data in an information system. DFD graphically represent the functions or processes which capture, manipulate, store and distribute data between the system and its environment and between components with in a system. The final outcomes from the DFD were context diagrams showing the system boundary and the DFD of the new logical system.

iii. Design and development

This stage emphasized the physical solution to user's information requirements (needs). The structure (user interface; application to application, application to database), relationships processes, procedures and functions were designed to show the general over view and interaction of the application system i.e. the general characteristic of the system was defined. Through document review of similar applications the researcher was able to

design the user interface, processes and functions of the application system. The advantage of using this kind of approach was that its cost saving in terms of materials accessed, a lot of time was saved and also a wide range of information was accessed which provided the researcher with knowledge on how to go about with this kind of application. The prototype of the design was developed at the design stage to get a feel of the application (System architecture).

System architecture

At this stage, the system architecture of the application was designed. The System architecture was designed using the three tier model called the **Model –Viewer-Presenter** (MVP) model because it provided an in-depth interaction during application designing. This model is also very beneficial in the development of Android applications because it segment the system design into three main tiers\ components i.e. user interface, application processes and data services. This architecture enables decoupling of components which provides an advantage of system survival and easy of trouble shooting at times of errors at design level. This model is used mainly in designing Android application systems i.e. User interface, Business processes and the Data services.

The **MVP** model was used in the designing of the system architecture in the following ways;

- < The **model** was responsible for managing the data of the application (database). It received input from the presenter. So here the researcher would follow this to design the database.
- < The **view** defined how the application data would be displayed (user interface). So this was used as a guide in the designing the user interface. The view would be implemented by activities, any Android widget or anything that could do operations like showing progress bars, updating a text view and others
- < The **presenter** received the inputs, optionally validates it and then passes it on (application processes). It involves the logics. It is responsible for querying the model and updating the views, reacting to user interactions updating the model. This was used in the designing the application processes and functions.

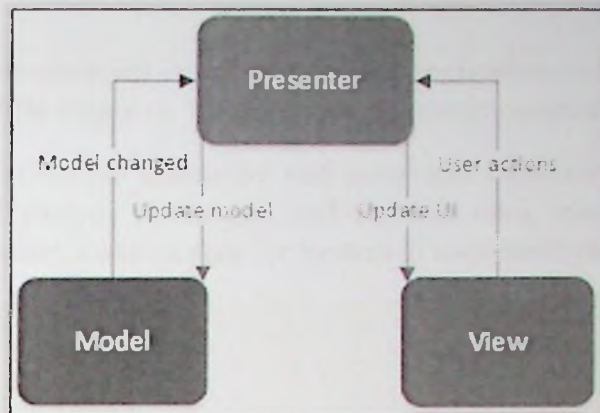


Figure 3: Diagrammatic representation of the MVP model for Android

Some of the model, processes and view in the application system;

Model

- < The system database containing information from the soil analysis, crop details and farmer information

Presenter/business processes

- < Soil analysis; this process analyzes the soil nutrient to attain results of soil nutrient content.
- < Computation and analysis of farmer information i.e. crop type to be grown, size of land to be used, the previous grown crop.

View

- < Fertiliser application rates and general information displayed.

The *Mrittika* model

This project also emulated the *Mrittika* model of design in order to best serve the farmer needs in the Ugandan context and with this there were additions in two major application functionalities;

- < The soil nutrient analysis component i.e. the application analyzes the soil nutrients and the **color** match of the test results is taken for accurate result interpretation by the system. The **Photo View** tool and **color recognition technology** were embedded in the tool. This supports for single point\ multi-touch for image zoom.

- < The soil recommendation component i.e. the application is based mainly on **soil PH** and **NPK** values i.e. the primary soil nutrient components.

The *Mrittika* model takes on the qualitative and numerical dimension of technology transfer i.e. for the soil analysis (in ranges) and fertiliser rates recommendation (in kilograms) respectively which makes it easy for farmers to understand the results.

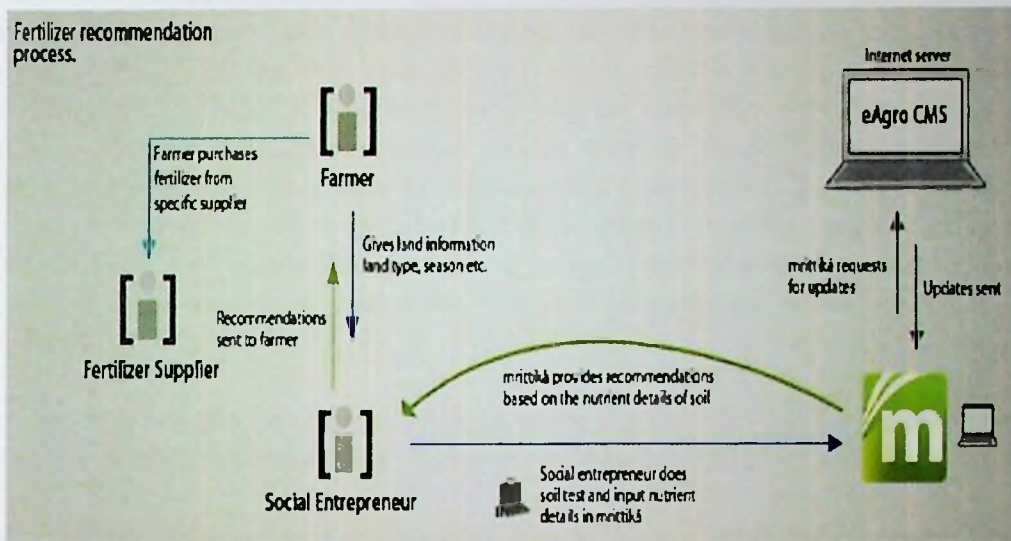


Figure 4: Mrittika fertiliser recommendation process model (Uddin, Md. J, et al 2013)

The System Architecture (SA) design of the soil fertiliser recommendation application system was used to achieve confidence that the design satisfies system requirements.

iv. Implementation and documentation

This phase signified the start of production. Implementation was done through document review, interview and the buildup of the application system processes, user interfaces and databases. Work flow charts were used to ensure the system processes are properly organized. According to Nick (2015), workflow diagram provide a visual representation of a business process or workflow, usually done through a flowchart. It uses standardized symbols to describe the exact steps needed to complete a process, as well as pointing out individuals responsible for each step.

The pilot method of implementation was applied. And here the new system was installed for about five (5) users. This method is particularly useful for new products, as it ensures functionality at a level that can perform in a real operational setting. The pilot method also allows a base of users to learn the new system.

At this stage, the real code was written to have the application running. It also involved creation of databases, preparing of test case procedures, preparing test files, coding and documentation.

At this stage the application system left the development environment as a signed APK in android studio and was put to the production environment (published in Google play store). In the production environment is where the users of the application (administrators and farmers) obtained access to the application and interacted with it. The development environment was also characterized by installation and changes in the application.

The application system was developed using the Android studio, Extensible Markup Language (XML) for the user interface (UI) and applications processes. The database was designed using SQLite. The reason as to why the researcher used Android studio and SQLite is because of its robustness and various dynamic features like visual editor that make it really fast for a developer to drag and drop which makes it easy. Android studio has many additional functions for advanced development. It offers back-end services like cloud database, push notifications, REST APIs, etc., multiple plugins for media, mailing, socials, to latest operating system support and technologies which makes it highly compatible.

The user interface for the different sections of the application (application activities) that were to be developed basing on the design in the initial design stage and these included;

- < Farmer information interface (this was to be the application's second activity interface); this captures farmer information (farmer name, contact and location)
- < Crop details interface and site characterization; this was to capture cropping details i.e. type of crop to be grown, land size land description and others.
- < Soil analysis interface; this was to analyze and capture the soil nutrient levels. This captures the information in ranges for easy understanding by the end user.
- < The records interface; this was to be designed and developed in a form format that returns most of the input data in the summary format including the fertiliser application recommendation after analysis.
- < The beans and maize interface; this was to provide basic agronomic practices those two crops

Fertiliser recommendation manuals

Soil fertiliser recommendation manuals developed by the Food and Agriculture Organization (FAO) and National Agricultural Research Laboratory (NARL) of Uganda on recommended fertiliser application rates in Uganda on annual crops specifically maize and beans were based on to give a bench mark recommendation in the system. These generalized recommendations are based on extensive research into fertiliser response

functions taken from new field trials undertaken by the National Agricultural Research Organization (NARO) and other data drawn from legacy research.

v. System testing and validation

This stage involved testing of the application and procedures' compliance. This was achieved through observation and case testing done by some selected farmers.

This was done to check for the system's requirements fulfillment like; capturing of the farmer information, crop details, analyzing of the soil nutrient test results and others, system documentation completeness with needs (if the intended sections like the crop section application really captures and returns the crops details in the summary report), the design and evaluation as per specifications i.e. does the design enable the farmer to access the intended fertiliser recommendation application rates easily. Testing was repeated specifically to check for errors and interoperability. This was to be done until when the end user found it acceptable.

With this, three forms of tests cases were used to test for the proper functionality of the application;

- ⟨ Functional acceptance test (FAT). To test for the intended functions or operations that are supposed to be carried out by the application. In our case, mainly recognition of soil test results and computation of recommended fertiliser application rates.
- ⟨ User acceptance test (UAT). Test if the application allows users to input into the required fields. This was to be done by users.
- ⟨ System test (ST). This would be carried out to determine the general functionality of the application i.e. does it fully function/ work.

According to Caliki.G (2010), function acceptance test verifies a program by checking it against the design specification. Interpretation of the user requirements according to their knowledge and test the software. User acceptance test confirms the usability from the end user's perspective. With clarity, it would be in line for the researcher to use these test cases for proof of functionality of the application.

Therefore, the above forms of test cases were deployed to test for the conformity and compliance of the application system. This would help to determine whether the application system complies with requirements specified, regulations and standards. It also dealt with some technical aspects like performance, functions, robustness, interoperability and behavior of the system.

The testing was carried out by a selected team comprising of Information technology experts for the technical aspects, agricultural extension staff and farmers for requirements, usability and problem solving. And due to the nature of the application that

was going to be used by people with little background in Information technology, it was very important to rule out any uncertainties.

Validation of the application

The validation process had mainly two steps as discussed below.

Step1

Sampling of soil. Soil samples were attained (following the sampling procedures) and subjected to analysis using the laboratory procedure, Makerere soil testing kit and the mobile application.

Step 2

Analysis and interpretation of the soil test results attained. This was intended to see if there was significant variance in results with the expert systems. This was aimed at comparison of the results attained. Here standard deviation and errors calculations were used to interpret the results.

Discussion of the validation process

This process involved comparing the results attained from an expert system (laboratory test; using classification by mehlh3 extractable nutrients) with that of the Makerere soil testing kit (using chemical reagents) and the mobile application for any deviations and errors in the results attained.

Soil samples were run through the three testing systems; Laboratory test (chemically), Makerere soil testing kit (reagents) and the mobile application for validation of the results. Four soil nutrients were looked at; Nitrogen, Phosphorous, Potassium, alkalinity (PH) as per the project's requirements.

Below are the equivalence values for the nutrient levels used in the laboratory procedure and Makerere soil testing kit for result interpretation that were used in the process.

Interpreting the values as per the Laboratory equivalence

	OM	N	P	K	PH
	%	%	ppm	ppm	
Very Low	0.7-1.0	<0.05	<45	<55	<5
Low	1.0-1.7	0.05-0.15	45-90	55-95	
Medium	1.7-3.0	0.15-0.25	90-230	95-150	
Adequate	3.0- 5.15	0.25-0.5	230-310	150-300	
High	> 5.15	>0.5	>300	>300	>5

Table 2: Table showing Classification of mehlh3 extractable nutrients

Interpreting of the Makerere Testing kit equivalence values.

Test results	Very low/lack	Inadequate/insufficient	sufficient	High
Color identification	No color change	Light blue	Blue	Deep blue
Equivalents(%N)	<0.1	0.1-0.19	0.20-0.29	>0.6
Equivalent kg N/ha	<20	20-38	40-58	>120

Table 3: Makerere Testing kit equivalence values for Nitrogen

Test results	Very low/lack	Low	Inadequate/insufficient	Moderate	sufficient	High
Color identification	No color change	No color	Green /light blue	Green	Blue	Deep blue
Equivalents mg/kg) P	<5	5-8	9-11	12-14	15	>20
Equivalent P ₂ O ₅ /ha	Multiply P by 2.29					

Table 4: Makerere Testing kit equivalence values for Phosphorous

Test results	Inadequate/insufficient	Sufficient
Color identification	No yellowish suspension	Cloudy yellowish suspension
Equivalents cmol/kg K	<0.10	>0.15
Equivalents ppm (multiply cmol/kg by 390)	<39	>58.5
Equivalent kg ha	<40	≥120

Table 5: Makerere Testing kit equivalence values for Potassium

PH	Brown	Dirty Green	Green	Blue
Alkaline >6	6	6.5	7	>7
	Brown	Green	Blue	
Acidic <5	4	4.5	5	

Table 6: Makerere Testing kit equivalence values for PH

Note: Makerere Testing kit equivalence values were used in the mobile application.

Interpretation

(%) = percentage, (ppm) = parts per million, (cmol/kg) = centimoles of positive charge per kilogram

P =Phosphorous, **K**= Potassium, **PH**= Acidity& Alkalinity

The attained results were used to calculate the standard deviation and error to validate the application.

The process also involved validating the Mobile application's ability to identify the attained nutrient color in comparison with the Makerere soil testing color chart (see appendix 9, Makerere soil testing kit guide). This was done to ensure that accurate color

match from the application was being done and this was done through observation of the soil test results attained using the mobile application in comparison with the color chart.

The mobile application was also checked for its functionality and accuracy to returning the detected color, nutrient level values and recommended fertiliser application rates. The equivalence values of the soil nutrients levels as per the Makerere testing kit were equated to the colors to enable the process. Therefore, once a color is detected, it has an equivalent value of the nutrient level or percentage of a given nutrient in a given sample space. It is upon these attained levels that recommended fertiliser application rates are calculated and given as output to the farmer/user (See appendix 6, Pseudo code). This was validated through observation of the output results attained.

Conclusively, the mobile application was validated through the calculation of the standard deviation and error to see the variance in the results attained by the application in comparison to the Makerere soil testing kit and laboratory procedures.

Procedure for calculation of standard error

Step 1: Calculate the mean (Total of all samples divided by the number of samples).

Step 2: Calculate each measurement's deviation from the mean (Mean minus the individual measurement).

Step 3: Square each deviation from mean. Squared negatives become positive.

Step 4: Sum the squared deviations (Add up the numbers from step 3).

Step 5: Divide that sum from step 4 by one less than the sample size ($n-1$, that is, the number of measurements minus one)

Step 6: Take the square root of the number in step 5. That gives you the "standard deviation (S.D.)."

Step 7: Divide the standard deviation by the square root of the sample size (n). That gives you the "standard error".

Step 8: Subtract the standard error from the mean and record that number. Then add the standard error to the mean and record that number. You have plotted mean $\pm$ 1 standard error (S. E.), the distance from 1 standard error below the mean to 1 standard error above the mean

vi. Deployment

This phase involved the actual installation of the newly developed application in the production environment (signed APK) and to bring it into operation. At this stage the design specified in the document was turned into executable programming language codes. The code was tested and mapped against the design document. At deployment the system ensured that;

- ⟨ It satisfied the functional requirements of interpreting, *analyzing soil* nutrients and providing recommended fertiliser application rates.
- ⟨ It satisfied the business need of enhancing the dissemination of timely recommended fertiliser application rates in order to increase on agricultural production which in turn increases small holder farmer's income.
- ⟨ And operates as described in the user and operator manuals.

At deployment phase, the intended users (farmers) and extension staff were trained on how to access, install and use the application, also the user and operational documentation done. The training was practical in the field for better demonstration and application of the system.

The deployment phase was carried out through publication of the application. This is a general term for making your application (signed APK) available to user. At this stage two main activities were done;

- ⟨ Preparing the application for release. Here a release version of the application was built and was made available for users to download and install on their android powered devices.
- ⟨ Release the application to users. Here the researcher distributed the released version of the application to users.

At deployment the following were also done;

- ⟨ Installation and activation; installation involved establishing some form of commands, shortcut, script or service for the executing the software (manually or automatically)
- ⟨ Deactivation; is the reverse of activation and refers to shutting down any already-executing components of a system. This was needed to perform other deployment activities like software update.
- ⟨ Update; the update process replaced the earlier version of all or part of a software system with a newer release.
- ⟨ Adaptation; is a process to modify a software system that has been previously installed. This is usually by local events such as changing the environment.

3.2 Methodology for soil nutrient analysis

Soil samples

Soil samples were collected (sampling procedures were followed as discussed in chapter four section 4.2 System study) and subjected to the different nutrient level tests for NPK, PH, and organic matter. The soil samples were collected from known places that had specific nutrient levels. The Soils department of Makerere University College of Agriculture and environmental Sciences (CAES) guided this since it had information and samples of most of the soils in central Uganda.

These soil samples were subjected to the Makerere soil testing kit test then followed by the Laboratory test for comparison and accuracy. In addition, during this process the different color codes and patterns were attained for use in the Application.

Synchronization and calibration

In order to increase on the accuracy level of the application, the soil samples were subjected to the laboratory for testing and results compared. For each of the nutrient tested for, they were subjected to different levels as seen below;

Nitrogen

- < Adequate (Deep blue)
- < Inadequate (light blue)
- < Lack of Nitrogen (no color change)

Phosphorous

- < High (Deep blue)
- < Adequate(light blue)
- < Moderate (green)
- < Low(no color change)

Potassium

- < Present (yellowish cloudy layer)
- < Not present(no yellowish cloudy layer)

PH

- < Neutral (purple), ≥ 6 , (6 brown, 6.5 dirty green, 7 green, > 7 blue)
- < Acidic (brown), ≤ 5 , (4 brown, 4.5 dirty green, 5 blue)

3.3 Color identification methodology/algorithm in the application

Color recognition involves comparison of every pixel within a given metric and leads to the dominant color because the colors of the given object are explained. The application has a built-in tool (algorithm) for extraction of colors and palettes from surfaces. The tool lets you pick single colors seamlessly with full support in smart gestures. The application also identifies the Color name and HSV representation code of the identified color.

How the color identification process is being done in the application (methodology)

- < In the Dashboard, .java class was used, called the DashboardPagerAdapter.
- < The DashboardPagerAdapter.java class launches the ColorDetectionFragment class.

- < The ColorDetectionFragment class will show a fragment that on which camera will be opened and detect a particular color.
- < For color detection we used some built in classes like Camera and Texture View
- < Camera class is used to access and focus the camera on a particular position.
- < Texture View class is extended in CameraColorPickerPreview and is responsible to pick a color and gives us the rgb values.
- < Because we need hex values that is why we convert the rgb values in to hex by using a formula.
- < There is a ntc.json file that is responsible for assigning respective hex values to detected colors in a range of rgb values.

How the colors are being compared and the algorithms being used for color matching in choosing the closest color match.

```
public static boolean compareHex(String hex1, String hex2) {
    int color1 = (int) Long.parseLong(hex1.replace("#", ""), 16);
    int r1 = (color1 >> 16) & 0xFF;
    int g1 = (color1 >> 8) & 0xFF;
    int b1 = (color1 >> 0) & 0xFF;

    int color2 = (int) Long.parseLong(hex2.replace("#", ""), 16);
    int r2 = (color2 >> 16) & 0xFF;
    int g2 = (color2 >> 8) & 0xFF;
    int b2 = (color2 >> 0) & 0xFF;

    return (Math.abs(r1 - r2) + Math.abs(g1 - g2) + Math.abs(b1 - b2) <= threshold);
}
```

Here we take two hexadecimal colors as input and convert them in to red, green, and blue colors getting their difference. After taking the difference we calculate the summation of absolute values using Math.abs functions by giving it to the red value of 1st hex number – red value of 2nd hex same as green value of 1st hex number – green value of 2nd and blue value of 1st hex number – blue value of 2nd.

For Example.

A hex code of gray is #CFD8DC and when we detect with camera if it returns #CFD8DD then this formula gives us 1 as output it means the difference between two hex codes is 1.

```
return (Math.abs(r1 - r2) + Math.abs(g1 - g2) + Math.abs(b1 - b2) <= threshold);
```

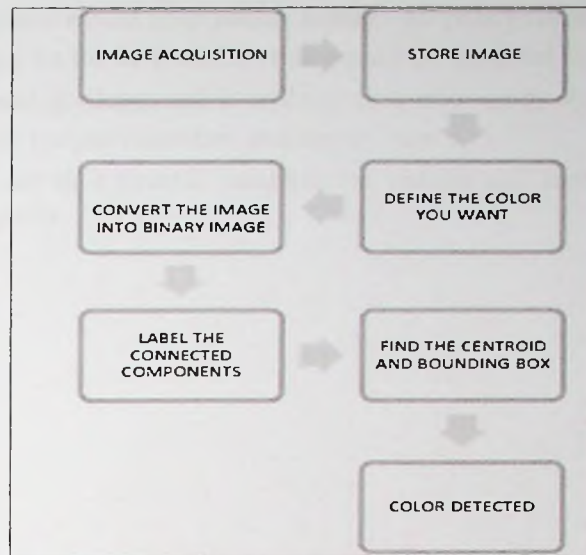


Figure 5: Flow chart of Algorithm in color detection

Camera focus (distance between the phone and the test tube)

The best camera distance of focus had to be determined.

3.4 Anticipated outcomes

- < Improved access to timely information; It would help farmers to obtain site-specific fertiliser recommendation application rates from the qualified agronomist and soil scientists. This is also one way to connect farmers to Agricultural Researcher thus reducing such costs hence improving on livelihoods.
- < The soil fertility rate recommendation system would help to address the global misuse of fertilisers that results in waste, soil damage, and groundwater contamination.
- < The soil fertility rate recommendation system will help enhance fertiliser management through provision of timely information concerning correct timing, placement and methods of fertiliser application and right source of fertiliser in order to maximize nutrient uptake and yield targets.
- < Another indirect livelihood outcome could be called as the "Digital Provide". The Digital Provide refers to the positive gain that those who do not directly own/relate to ICTs get from the externalities that ICTs bring in (Heeks, 2010). Through the application, ICTs bring in better efficiency in the agricultural supply chain as well as output. This, in the long run can also help the farmers who are a part of the same community but who are not associated with fertiliser application

- < The information system would help policy makers on policy drafting and guide towards fertiliser usage basing on the information that would be obtained from the system.
- < After being tested and implemented it will act as a pilot study for further improvement and reference to other projects scholars and researchers.
- < The system would act as a central database for unique soil nutrient test result in the central region of Uganda.

Chapter Four

4.0 Presentation of field results, system study and analysis and requirements

Introduction

In this chapter, the researcher presents analysis and interpretation of data that was collected following specific objective one of the study that was to establish the requirements needed to develop a mobile application in order to enhance the dissemination of recommended fertiliser application rates information (Information and system requirements).

This chapter goes ahead to show how the waterfall model in the system development Life cycle (SDLC) indicated in the methodology was used to fulfill the project major objective of developing a mobile application that interprets, analyzes and provides recommended fertiliser application rates to farmers. The model included requirement identification, designing and development, implementation, system testing and deployment. These were put into use to achieve the results being presented. This method consisted of completing a stage then moving to the next step. Each stage depended on information from the previous stage. The model allows the opportunity to return to an earlier stage, however going back to a previous stage involves an extra cost of rewriting for both documentation and developing the application.

The requirements were gathered through interviews that were conducted with a targeted group of participants (75) who were carefully selected using purposive sampling method. The results represent the statistics of the interview and these guided the requirement for the development of the application. These requirements statistics were taken seriously since they acted as a yardstick for the challenges being faced and guided the development of the solution. Further to note is that these statistics and characteristics were transformed into the processes and design of the mobile application. The findings were analyzed using the Statistical Package for Social Scientists (SPSS) for the frequencies and interpretation.

This section describes the current process through which soil nutrient levels and fertiliser recommended rates information are attained by farmers in the farming communities. The interaction between the users and the application was showed through the dataflow diagram.

4.1 Presentation of requirements results

i. Summarized responses of training attained on the use of soil testing kit to get nutrient levels and how many times

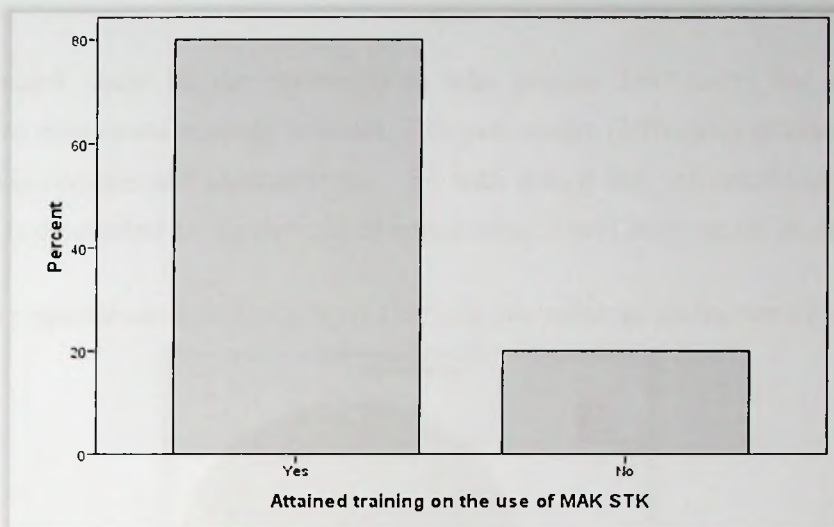


Figure 6: Showing percentage of respondents who attained training on the use of soil testing kit

Figure 6 indicated that 80% of the respondents had received training on the use of soil testing kit and 20% didn't have any training. And this percentage (80%) helped on requirement identification and determination hence easing on the requirements process for the application development.

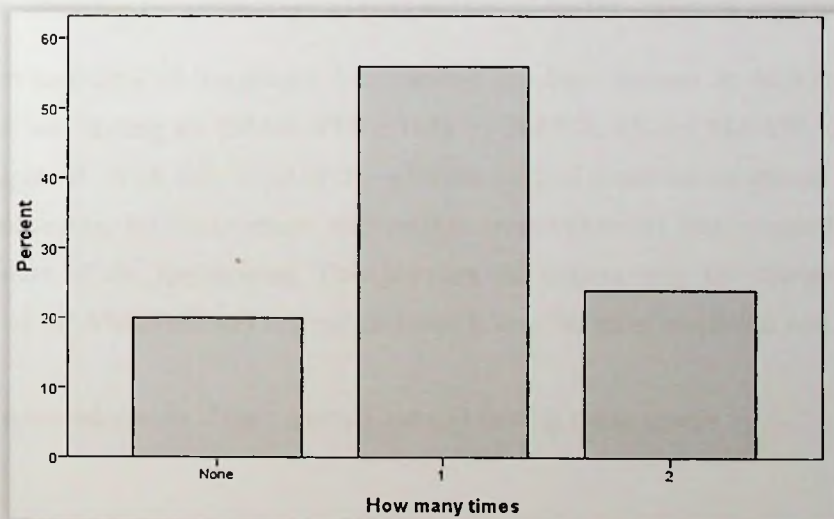


Figure 7: Showing the percentage of times people attained training on the use of soil testing kits

Figure 7 showed that 56% of the respondents had attained training on the use of soil testing kit once (1 time), 24% had training twice (2 times) and 20% didn't have any training at all. Based on the statistic attained, although 80% of the people interviewed had training, 56% of them had

training once which could be the reason as to why people don't carry out soil testing by themselves due to inadequate training attained. This percentage (56%) ably provided information that also helped in requirement identification. So with this, it also informed the researcher that if more training is conducted on the developed application, it will increase on its usage.

ii. Summarized response on organizations that carried out trainings on the use of soil testing kit.

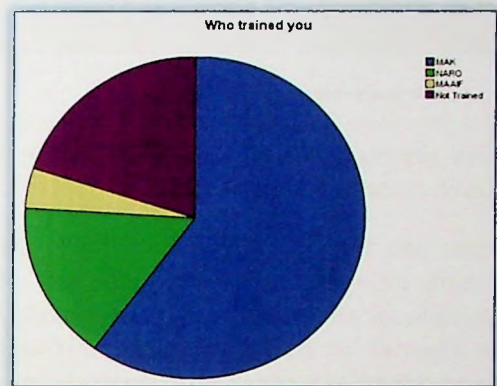


Figure 8: Showing the percentage of people trained by the different organizations

Figure 8, showed that 60% of the people interviewed had been trained by Makerere University on the use of the soil testing kit (MAK STK), 16% by NARO, 4% by MAAIF and 20% didn't have any training at all. With this, most of the information and experiences shared were based on the Makerere soil testing kit hence more information (requirements) was attained which guided on the development of the application. This justifies the reason why the researcher based his work on the use of the Makerere soil testing kit since it was the most available soil testing kit.

iii. Response of respondents on if they carried out soil testing them selves

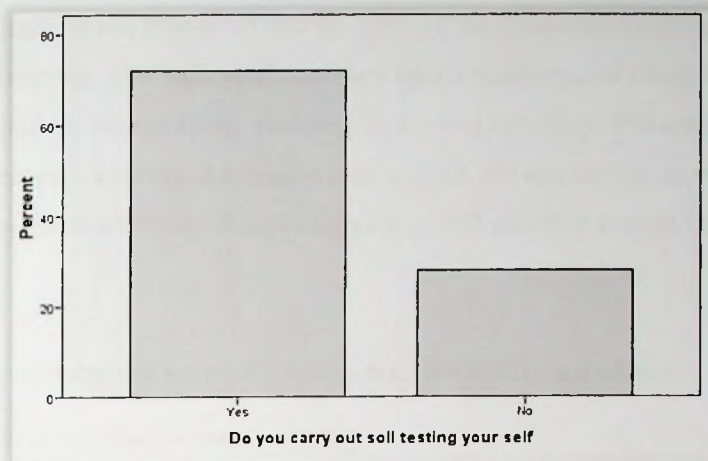


Figure 9: Showing the percentage of people interviewed who carry out soil nutrient tests by themselves

The statistic in figure 9 above indicated that 72% of the respondents carried out soil tests themselves. With this, 28% was representative enough to give reasons as to why they didn't carry out soil testing which guided on the requirements identification. This helped in identifying the hindrances and challenges that are being faced by farmers while carrying out soil nutrient analysis which were used to guide especially in the design process and the result output.

iv. Summarized reasons as to why people don't carry out nutrient tests

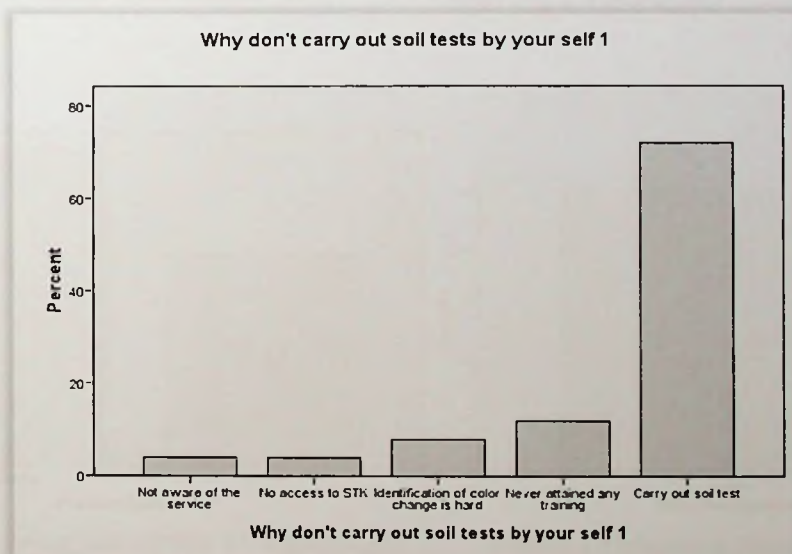


Figure 10: Showing the percentage of reasons as to why people don't carry out soil testing

From the analysis made in the figure 10 above, 12% of the respondents indicated that they had never attained any training, 8% indicated that they had a challenge in identification of color, 4% indicated that they had no access to the soil testing kit and the other 4% were not aware of the service. It's upon this result of the challenges that guided the development of the application to provide a solution to the interpretation and analysis of soil nutrient results that was being faced by farmers.

v. Summarized response on soil nutrients which are commonly tested for.

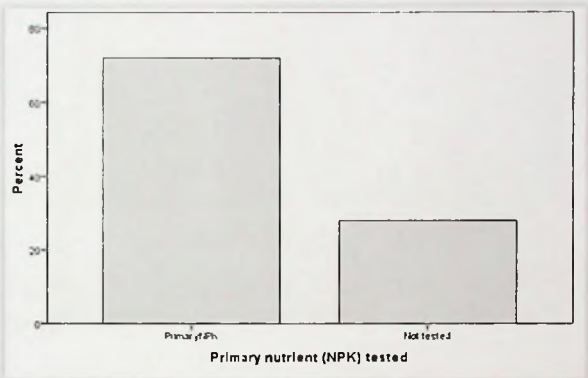


Figure 11 : Showing the percentage of respondents Interviewed who test for NPK



Figure 12 Showing percentage of respondents who test for PH levels

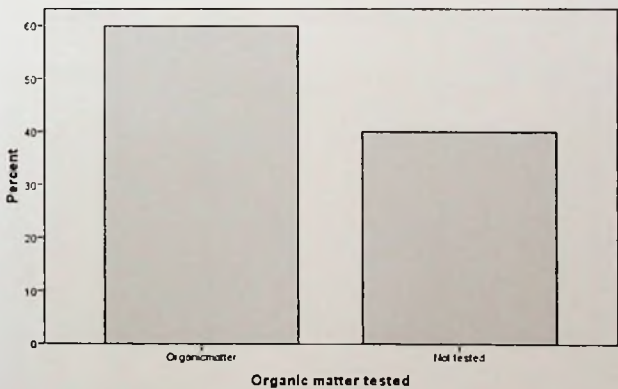


Figure 14 Showing percentage of respondents who test for Organic matter levels

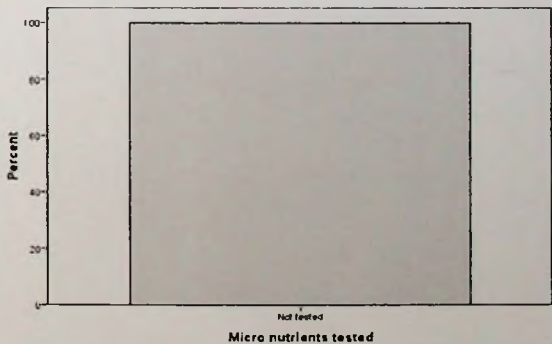


Figure 13 Showing percentage of the respondents who test for Micro-nutrient levels

From the analysis carried out, the result showed that Primary nutrients (NPK) and Soil PH were the highly tested for components at about 72% each, followed by Organic matter at 60%. It was also observed that Micro nutrients were the least tested for nutrients at 100% no test. So this statistic guided the researcher on what nutrients that should be considered for the mobile application interpretation and analysis i.e. NPK, PH and Organic composition.

vi. Response on the crops upon which mineral fertilisers are commonly applied.

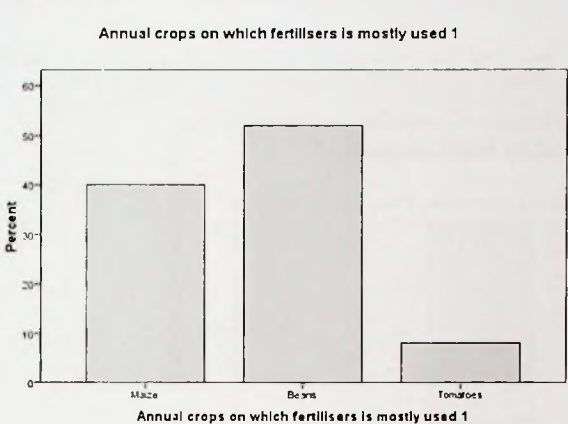


Figure 15: Showing the percentage of crops mostly applied on fertilisers

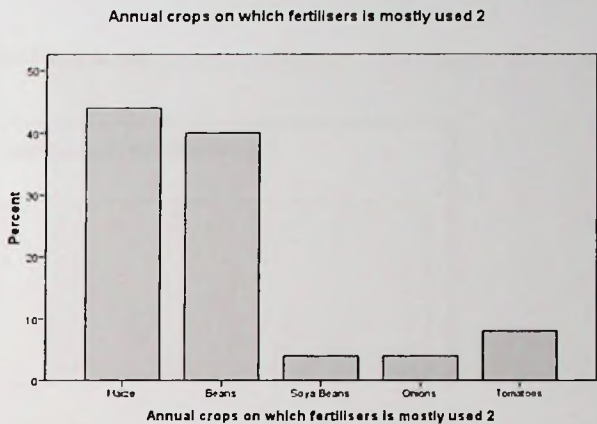


Figure 16: Showing the percentage of crops mostly applied on fertilisers

From the analysis carried out as seen in the figures 15 and 16, Beans appeared to be the most applied on fertiliser crop at around 52% followed by Maize at around 40% then at around 24% Soybeans. So statistics guided the researcher on what crops to consider in the application system for consideration of fertiliser application.

vii. Mineral fertilisers commonly used

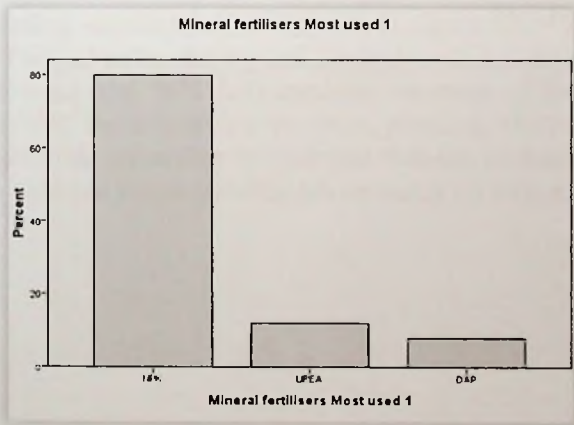


Figure 17: Showing the percentage of mostly applied mineral fertiliser (NPK)

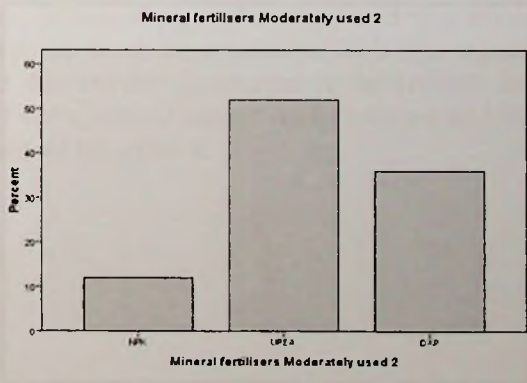


Figure 18: Showing the percentage of moderately and commonly used fertiliser

From the statistic seen in figure 17 and 18, it clearly comes out that NPK is the most applied mineral fertiliser at about 80%, followed by UREA at about 52% and the DAP. This guided the researcher on what kind of fertilisers to consider in the application for the specified crops including their application ratios and methods.

Viii. Challenges faced while carrying out soil nutrient tests

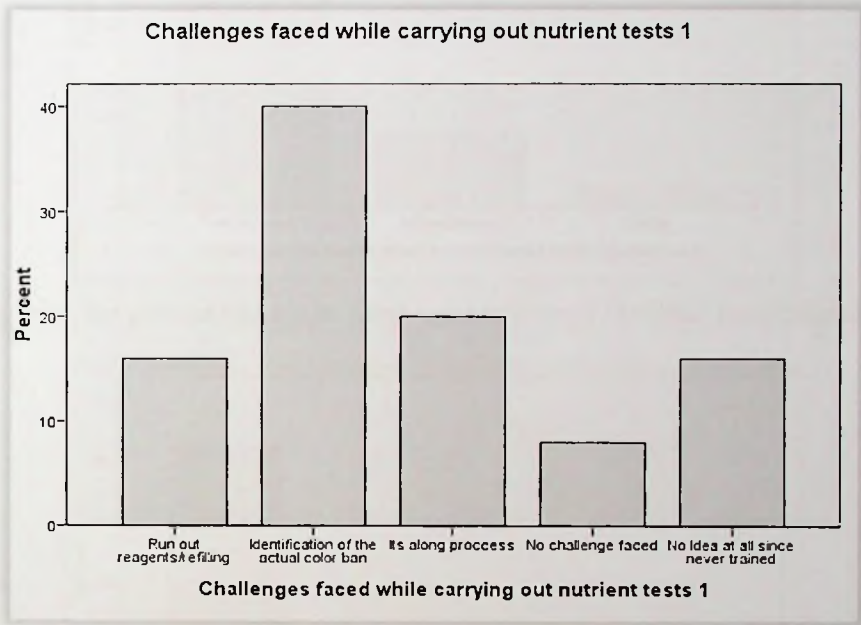


Figure 19: Showing the challenges faced by individuals while carrying out nutrient tests

Basing on the analysis as seen in figure 19, 40% of the respondents indicated that identification of actual color during soil analysis was a challenge, 20% of the people mentioned that it's a long process and 16% indicated the shortage of the reagent used for analysis. With this statistic, it guided the researcher on most pressing challenge that needed a solution to be crafted. So this gave the researcher confidence that the problem of color identification really existed and needed a solution hence guiding his research on where to direct his efforts.

ix. Where do farmers attain recommended fertiliser application rates?

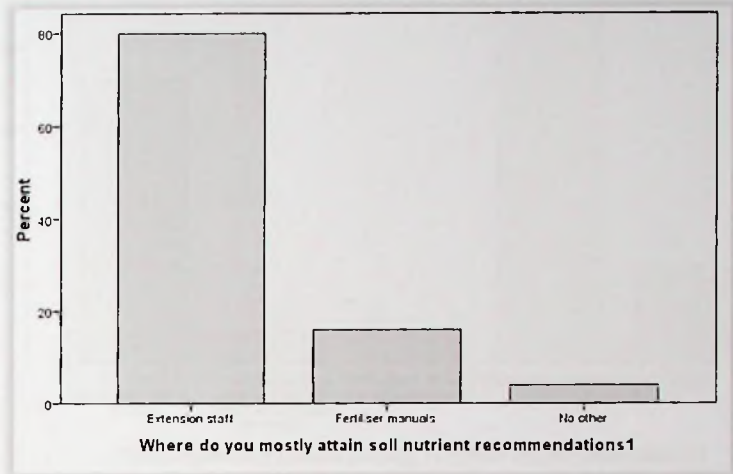


Figure 20: Showing the percentage of the most used source of fertiliser recommendation

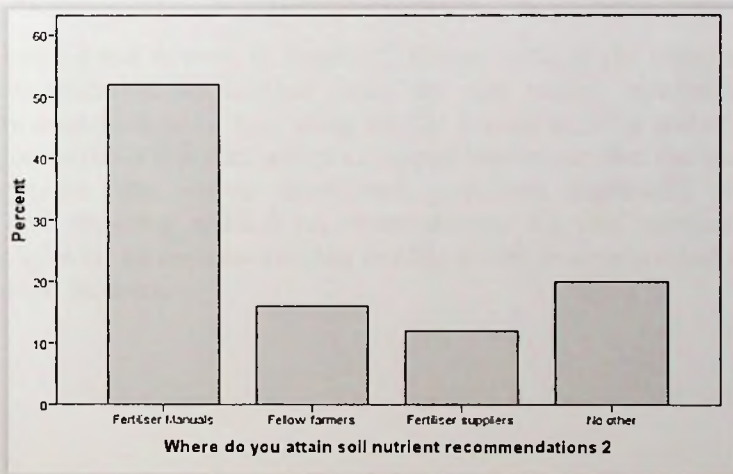


Figure 21: Showing the percentage of the main sources of fertiliser recommendation

From the analysis done in figure 20 and 21, 80% of the interviewed people showed that they get fertiliser recommended rates from extension staff followed by fertiliser manuals. This statistic equipped the researcher with information that guided him on fertiliser source distribution hence guiding the application development process. If the application provides the recommendations then the costs on extension staff will be drastically reduced hence saving on production costs. This greatly motivated the development of the mobile application.

x. Challenges faced while getting recommended fertiliser application rates

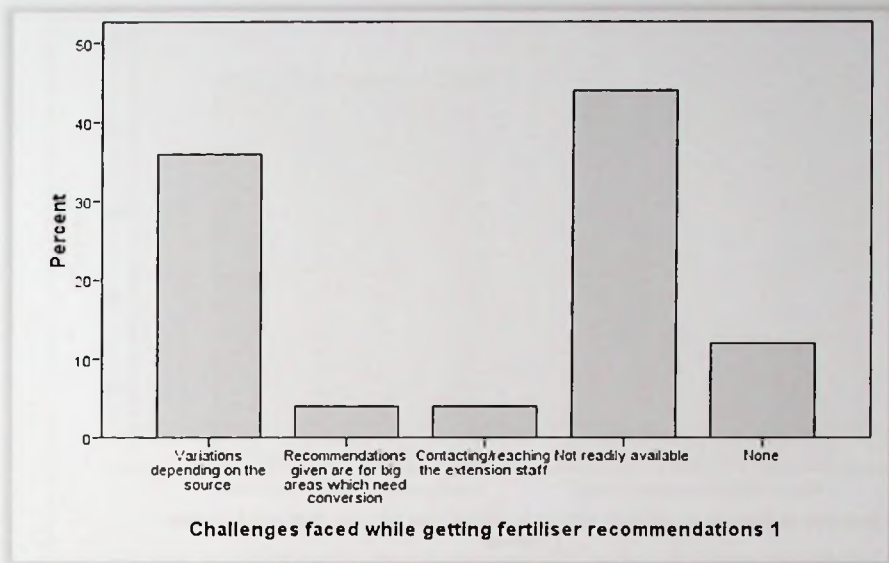


Figure 22: Showing the percentage of the challenges faced by farmers while attaining fertiliser recommendation

From the analysis carried out as seen in figure 22 above, 44% of the respondents indicated that the fertiliser recommendation application rates are not readily available followed by the variations of recommendation rates depending on the source at 36% and others. This provided empirical information to the researcher which equipped him to see that the study comes up with a solution that can solve the above mentioned problems especially of readily availing recommendations and attaining unified recommendation. So this motivated and guided the researcher to come up with an application that readily avails recommended fertiliser application rates information to the farmers.

xi. The kind of information they would want a mobile application to provide to them concerning soil fertility

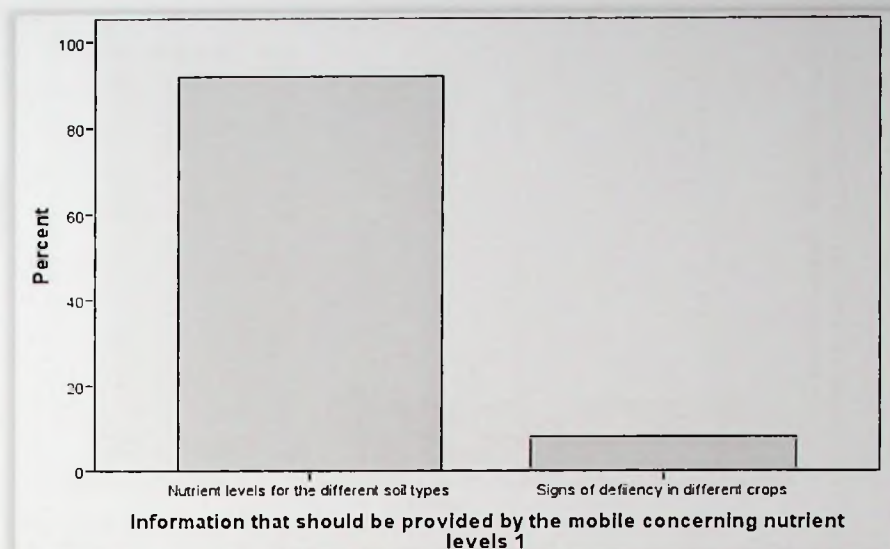


Figure 23: Showing the percentage on the information that should be provided by the mobile application

From the analysis carried out as seen in figure 23, 92% of the correspondent interviewed indicated that they needed to be provided with nutrient levels for the different soil types and 8% needed to be provided with signs of deficiency in different crops. This guided the researcher on the requirements information for the application output in order to benefit the farmers.

xii. The kind of information they would want a mobile application to provide to them concerning soil fertility.

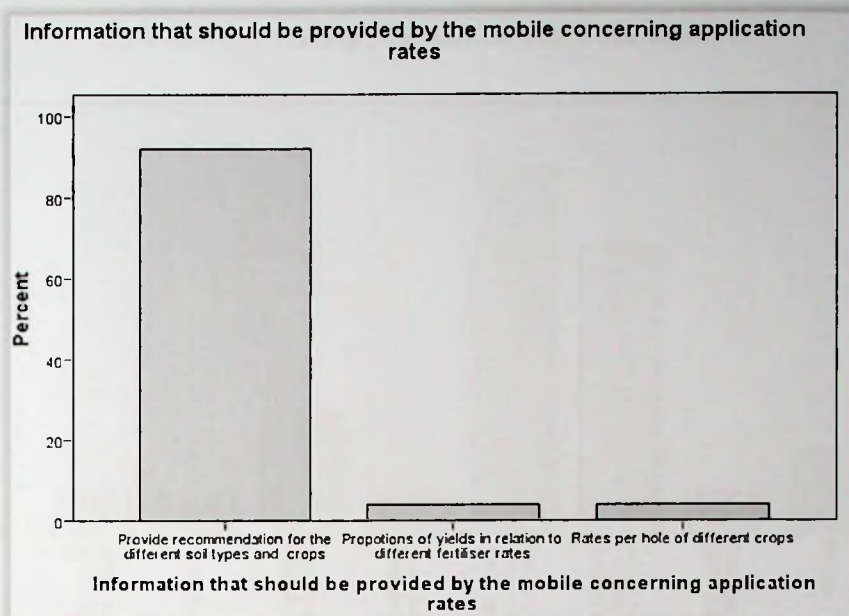


Figure 24: Showing the percentage information that needs to be provided by the mobile App concerning application rates

Basing on the analysis carried out, figure 24 indicated that 92% of the respondents interviewed indicated that they need the mobile application that provides recommendation rates for the different soil types and crops, 4% of the people indicated that the application needs to avail proportions of yields that would be attained after using different rates of fertilisers and the other 4% indicated that the application should provide fertiliser rates needed per hole for the different crops. With this kind of expectations, it guided the study's processes and design to see that it yields some of the farmer expectations.

Xiii. How the soil testing process could be improved upon.

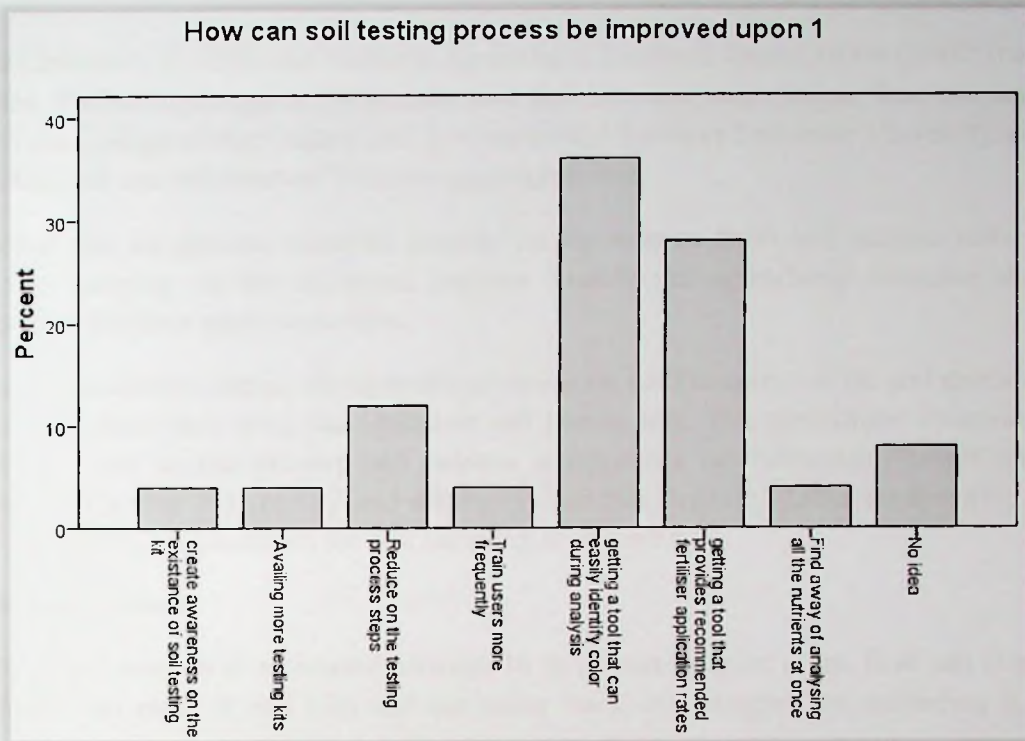


Figure 25: Showing response of participants on how the soil testing process can be improved

Basing on the analysis as seen in figure 25, 36% of the respondents interviewed indicated that they need a tool that can easily identify color during the analysis, 28% indicated that they need a tool that provides recommended fertiliser application rates readily, 12% indicated that they need a system that can reduce the time of testing process. With this kind of information, it guided the research to design and develop an application that can fulfill the farmers' desires hence improving on the soil testing process and availing timely onsite recommended fertiliser application rates.

In conclusion, these attained statistics and characteristics guided the system processes and design of the mobile application i.e. they were transformed into the design of the application.

4.2 System study

The researcher critically observed the current process of analyzing soil nutrient levels and attaining recommended fertiliser application rates information by farmers. It's from this critical analysis and observation that the current business process model was generated to help in the requirements gathering and also give the researcher a clear understanding of how soil nutrients levels are attained and how information flows through the entire chain up to the acquiring the recommended fertiliser application rates. The process involved interacting with various stake holders that would use the application. These included the farmers, agricultural extension staff, and soil scientists from research Institutions (College of Agriculture and Environmental Sciences

Makerere University (CAES) and National Agricultural Research Organization (NARO) and the Information Technology experts. With this, five farmers were interviewed; four soil scientists (two from the College of Agriculture and Environmental Sciences Makerere University and two from NARO) and one Information Technology programmer.

It was noted that the process involved majorly on the outputs from soil nutrient tests results attained after carrying out the nutritional analysis done by the agricultural extension staff and recommending fertiliser application rates.

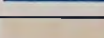
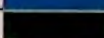
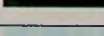
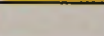
In summary, the farmers contact the agricultural extension staff to carry out the soil nutrient level testing on their farm land using the Makerere soil testing kits. The agricultural extension staff carries out the test on the primary soil nutrient components i.e. Nitrogen, Phosphorous and Potassium (NPK), Soil PH (acidity and alkalinity) and the Organic Matter composition of the soil. The recommended procedure for soil sampling is followed.

Soil sapling procedure

Soil samples are attained at a distance between 10 to 20 meters apart in the field and at a depth of 0 to 20cm. not close to anti hills and not under trees, and samples not exceeding 0.5kg in weight.

Soil testing/analysis procedure

A small quantity of the soil sample (a teaspoon or spatula full) is put in the test tube. Distilled water and different reagents in different quantities as guided in the Makerere soil testing kit guide (see appendix 9) is added to the soil sample in the test tube. The soil solutions in the test tubes react and indicate different colors depending on what is being tested for as seen in the table below;

Nutrient being tested	Color	Image	Levels\Indicates
Nitrogen	Deep blue		Adequate
	Light blue		Inadequate
	No Color change		Lack of Nitrogen
Phosphorus	Deep blue		High
	Light blue		Adequate
	Green		Moderate
	No Color change		Very low
Potassium	Distinct cloudy yellowish layer		Sufficient available potassium
	No yellowish cloudy layer		Deficient potassium

PH	Purple		Is greater than 6(>6)
	Brown\yellow		Is less than 5(<5)

Table 7: Showing different nutrient level colors

The above color reactions apply to Nitrogen, Phosphorous, Potassium and PH. The reaction for presence of Organic matter is quite different as discussed below.

Organic Matter (OM)

A small container (like a bottle top) is filled with a soil sample and mixed with 4-5 drops of reagent OM. The vigorous reaction when reagent OM is applied directly to the soil sample indicates high organic matter presence, a faint reaction indicates low OM presence ; 0-5 seconds of reaction is considered low, 5-10 seconds of reaction is considered high and 10 seconds on wards is very high Organic matter content.

Reagents used in the Makerere Soil testing kit

- For Nitrogen testing, the N1 and N2 reagent are used.
- For Phosphorus testing, the P reagent is used along with a metal foil which is provided in the kit.
- For Potassium testing, the K1 and K2 reagents are used.
- For the soil PH testing, D1, D2 and D3 dye indicators are used.
- For Organic matter testing, OM reagent is used.



Figure 26: The soil testing kit (MAK STK)

The soil test kit (MAK STK) is used to test for five (5) soil fertility parameters. These are PH, Organic matter (OM), Nitrate nitrogen (N), Phosphorus (P) and Potassium (K). These parameters are considered to be very critical for proper plant growth.



Figure 27: Testing for chemical reagents

Fertiliser recommendation acquisition

Basing on the soil nutrient levels (indicators) attained by the agricultural extension staff, fertiliser recommendation rates are calculated for application. This also depends on the crop to be grown. The fertiliser recommended application rates provided by the agricultural extension staffs are usually got from manuals developed by the National Agricultural Research Laboratory (NARL), manuals from the College of Agriculture and Environmental Sciences (CAES) in Makerere University and other soil fertility related Institutes. Below is the high level business model for attaining recommended fertiliser application rates as described above.

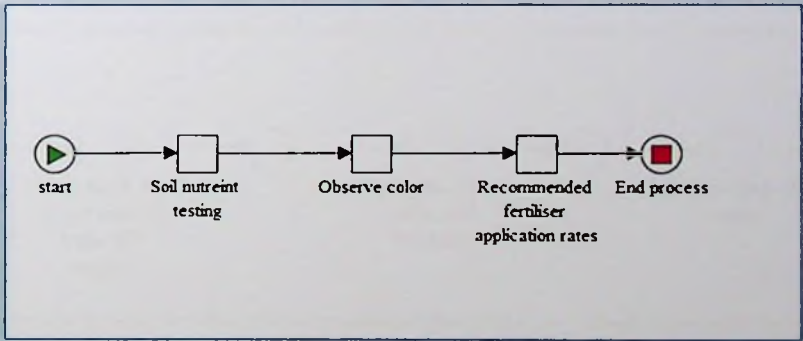


Figure 28: Showing a high level business process model for attaining recommended fertiliser application rates

Sub-business process model during soil testing

During the soil nutrient testing process, each soil nutrient component (NPK, Organic Matter and PH) is tested for differently. Below are the sub business processes for each soil nutrient tested for during soil analysis.

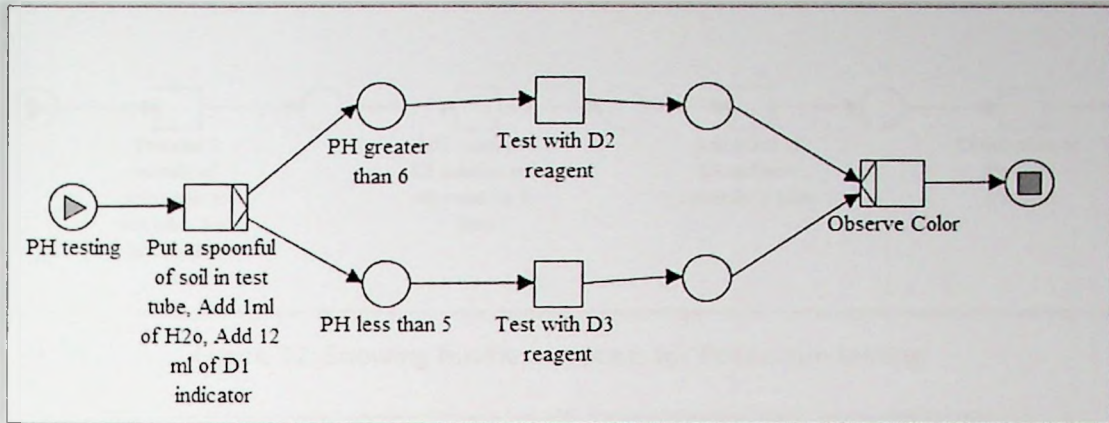


Figure 29: Showing business process for soil PH testing

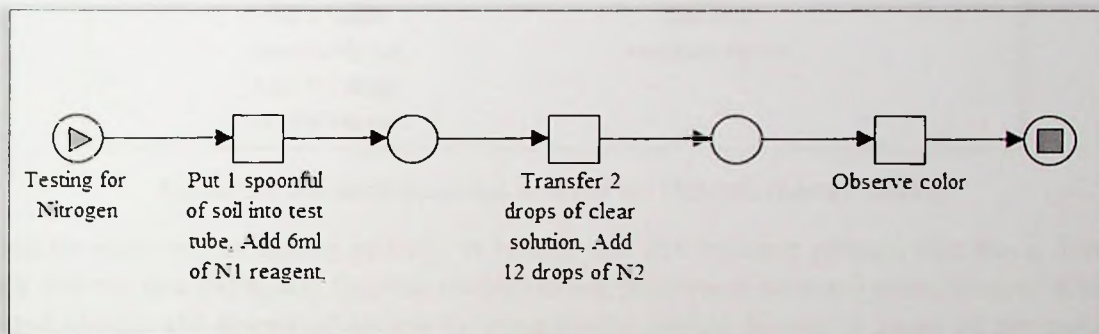


Figure 30: Showing business process for Nitrogen testing

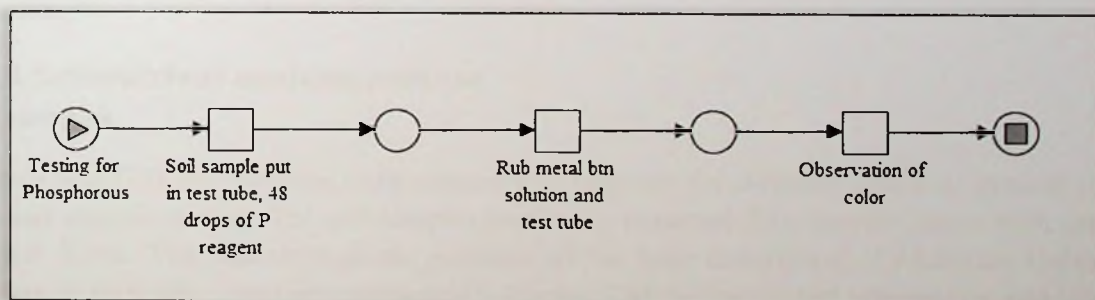


Figure 31: Showing business process for Phosphorous testing

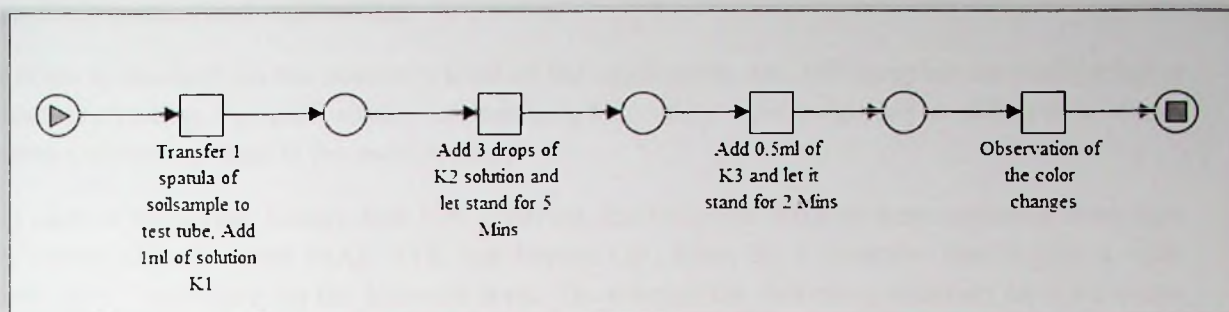


Figure 32: Showing business process for Potassium testing

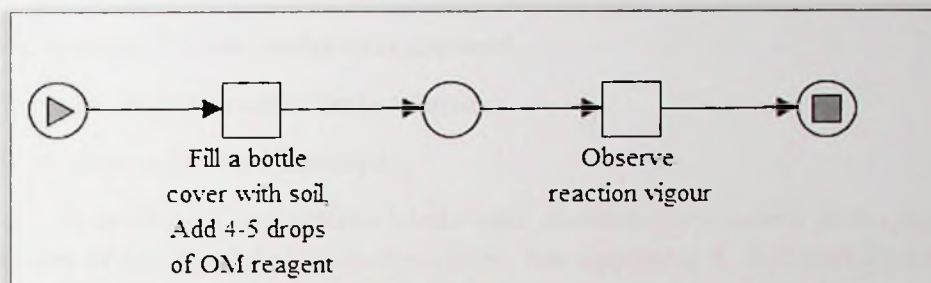


Figure 33: Showing business process for Organic matter testing

During the soil nutrient testing process, it is only soil PH business process that has a deferred choice and the rest (NPK and Organic matter testing processes) have sequence choice. With the deferred choice, the thread of control is immediately passed to one or more of the outgoing branches based on a mechanism that selects one or more outgoing branches. The choice is made by the environment not the system. For the sequence pattern of process, an activity in a workflow process is enabled after the completion of a proceeding activity in the same process or no branching.

4.2.1 Soil nutrient analysis process

Soil samples

Twenty five (25) soil samples were subjected to tests for the different nutrients present (NPK, PH, and organic matter). The soil samples used were collected from known places with specific nutrient levels. This was through the guidance of the Soils department of Makerere University College of Agriculture and environmental Sciences (CAES) since it had information and samples of most of the soils in central Uganda.

The soil samples were subjected to the Makerere soil testing kit test then followed by the Laboratory test for comparison and accuracy. During this process, the different color codes were attained for and used in the Application that was developed.

Synchronization and calibration

In order to increase on the accuracy level of the application, the soil samples were subjected to laboratory testing. For each of the nutrient tested for, they were subjected to different levels of nutrient content as seen in the methodology.

For each of the levels, twenty four (24) different results (color images) were captured from each i.e. twelve (12) from the MAK STK and twelve (12) from the Laboratory test to give a wide cover hence increasing on the accuracy level. On average the following numbers of color codes were obtained;

Nitrogen; 72 color codes were captured

Phosphorous; 72 color codes were captured

Potassium; 44 color codes were captured

PH; 44 color codes were captured

The color results for the various nutrient levels were coded and embedded in the application for the computation of recommended application rates. See **appendix 8**; Soil nutrients testing color codes

Camera focus (distance between the phone and the test tube)

It was observed that at a distance between 10 and 15cm, the camera gave the best resolution of the color being captured from the test tubes. And with that, a distance between 10 and 15cm or half foot was used. Phone cameras with pixels between 5 and 16 were used during. This was so because most the phone cameras with farmers and on market are within that range.

4.3 Requirements

Basing on the analyzed statistics, characteristics and literature as seen in chapter 4 subsection 4.1 (field results) and other sections, the user requirements, functional and non-functional were determined by the researcher after interacting with the intended users. This helped the researcher to meet specific objective one of the study to establish the requirements needed to develop a mobile application. The results attained from the field were translated into the system requirements.

4.3.1 User requirements

After interacting with the intended user (farmers and extension staff) through interviews, the researcher was able to analyze statistics and get the user requirements as elaborated below;

1. They needed an application that provides fertiliser recommendation rates for the different soil types and crops
2. They needed a tool that can easily identify color during soil test analysis
3. They needed a system that can reduce the testing process time.

4. They needed an application that provides fertiliser rates per hole for the different crops
5. They needed to be provided with nutrient levels for the different soil types
6. An application that can avail proportions of yields that would be attained after using different rates of fertilisers
7. They needed to be provided with a tool that detects the signs of nutrient deficiency in different crops(diagnostic tool)

It was from these requirements; that the researcher summarized, internalized and teased out the major challenges that were being faced by farmers as far as soil nutrient analysis and fertiliser application rates is concerned, which needed a solution. The user requirement were identified as seen below;

1. An application that could easily interpret and analyze soil nutrient results after carrying out the tests. It should be in position to interpret and match the colors attained (soil nutrient interpretation).
2. An application that could provide them with recommended fertiliser application rates for the major crops i.e. beans and maize after carrying out the nutrient tests on their fields (generation of recommended fertiliser application rates).
3. An application that could provide them with the different fertiliser types and where they can be get them (Generation of available fertiliser types for specified crops (maize and beans)
4. An application that is easy to navigate through and get the results easily with less input to reduce on the chances of many errors (User friendly interface)
5. An application that enables the users to keep record of the attained results; soil nutrient test, the recommended fertiliser application rates (Save results (keep record)

4.3.2 Functional requirements

The functional requirements were generated from the in depth review of the business process and interviews held with the farmers and other stakeholders. These requirements highlight the activities and operations the application should perform to meet the expectations of the different stakeholders.

Analysis of the soil nutrient

To make sure that the application recognizes the soil nutrient results, interprets them and analyses them for the farmer.

Analysis; to make sure the application interpret and analyze results separately (NPK, PH and Organic matter differently)

Generation of recommended fertiliser application rates

To be able to analyze data input and avail recommended fertiliser application rates to the users easily for the farmer.

Authorization (grant access)

Maintain proper specification of access rights privileges to different user interacting with the system

User-friendly Interface

To enable users comfortably navigate through the application with ease.

4.3.3 Non-functional requirements

The non-functional requirements of the fertiliser recommendation application specified how the system should work and behave. Below are the non-functional activities that gathered during the process review through observations and interviews with the farmers.

Accessibility

The application should be readily available and accessible to authorized users whenever required since it is a mobile phone application.

Reliability

The application developed should ensure that it satisfactorily performs the tasks for which it was designed for which was to enhance on the availability of recommended fertiliser application rates.

Efficiency

An application that would provide the correct results when correct input has been fed into it and prevent the users from making by validating their input and displaying recommended fertiliser application rates.

Speed

Users need an application which is quick and gives timely and accurate results.

Robustness

Stability should be maintained despite the amount of data fed into the application over the time. It should be in position to contain and continue to operate.

Consistency

A well-defined pattern in terms of layout and structure is another key attribute presented for the users. For example the labels or icon to mean the same thing throughout the application.

Recoverability

The tool designed has to be able to perform regular backups of the database and maintain a redundant copy of all data being processed and data processed in the system. This comes in handy during recovery process

Input validation

If a user leaves a mandatory field blank, he/she should be prompted to enter valid data in that particular field. This prevents inserting blank spaces, wrong data in the database which leads to dirty data

4.3.4 System requirements

The system requirements can be categorized into two i.e. hardware requirement and software requirements; basing on literature and analysis of similar developed applications, the following system requirements were considered.

The hardware requirement

Mobile phone requirements

Screen size of at least 5.0 inches
Android operating system: version 4.0 upwards
RAM of at least 512MB
Space of at least 1GB
Camera of at least 5mega pixels

Server

Processor: Intel processor 2.4 GHZ, 24000 MHz
Memory: At least 16 GB RAM DDR3
Storage: 2 TB SATA
I/O ports: PCI slots
Network: Embedded NIC 1000 (Giga Ethernet)
Power: 240 W

Software requirements

Operating system: Windows server 2012R2
Android studio 7+, Java, MYSQL 8 DB server, SQLite

Holistically through the enterprise architecture, the requirements were summed up as seen below. It shows the relationship between the different components used; hardware and software.

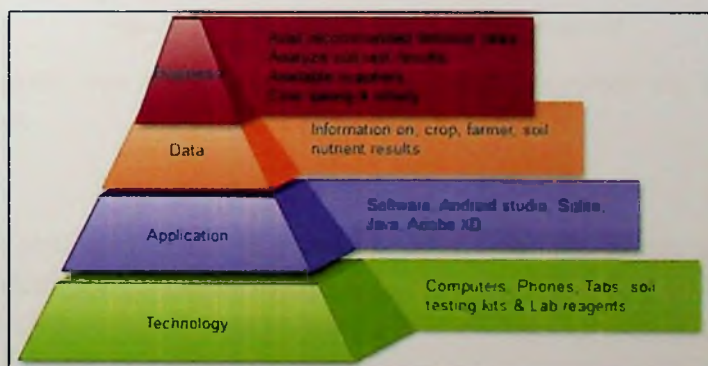


Figure 34: Enterprise Architecture

4.4 System design

This section describes the underlying elements of the application during development. It highlights the blueprint of the application the researcher followed when implementing the system functionality and operation in order to meet the set objectives. With this section, the researcher met specific objective two of his research work i.e. Design the mobile application's processes, functions and structure in order to get an insight of the application before development. At this stage, the requirements analyzed guided the development of the design and the processes i.e. the requirements statistics provided information for the design on how it should be in order to meet the main object of developing an application that interprets, analyzes and disseminates recommended fertiliser application rates to farmers. This guided on the kind of database, interface and other processes needed. Using the Data flow Diagram (DFD), the researcher was able to show the interaction between the user and the application system.

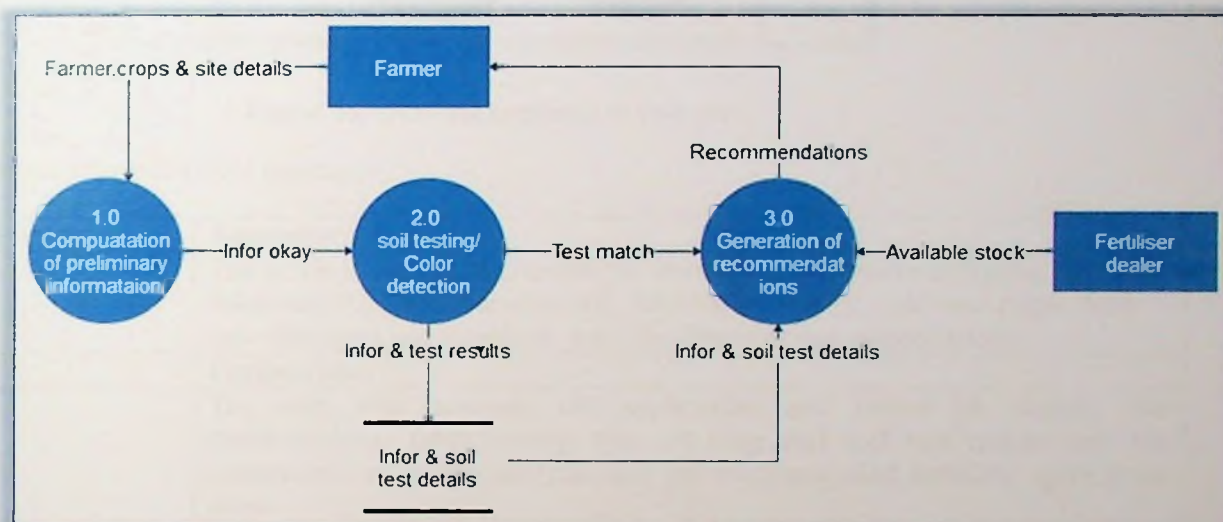


Figure 35 showing the Data Flow Diagram

The data flow diagram was used to show the interaction between the user and the system application processes.

Use case

This technique was also used to describe the functionality of the mobile application. Each use case represents a specific flow of events in the application and therefore each description of a use case defines what happens when the use case is performed.



Figure 36: Showing application Use case

Events/activity for individual use case

Use case name	Administrator
	The administrator is responsible for managing the system including its database ; Add site characteristic, Add Farm History, Add new crops, Add new fertilisers and suppliers, add new fertiliser recommendations
	Farmer/User
	The user who accesses the application and enters his details, site characteristics, farm history, type of crop and soil test results into the application to do the analysis and get recommended fertiliser application rates
Description	Farmer details
	The farmer/user enters his credentials and location into the application
	Site characteristics
	The farmer enters the site description; nature of slope and others
	Farm history
	The farmer enters the farm land history; presence of crops and common weeds available
	Crops to be grown
	The farmer selects the type of crop to be grown
	Soil testing/analysis
	The farmer captures the soil test results using the mobile application to perform analysis
	Computation of recommended fertiliser application rates
	The application computes the recommended fertiliser application rates basing on the soil test results

Table 8: Showing Activities for use case

4.4.1 Physical Database design

It's at this design stage, that the identified entities and relationships between these entities are represented. A database schema was designed as shown below and an Entity Relationship Diagram (ERD) generated to give a clear view of the entities and matching relations. Below is figure 37 showing the entities that were identified in the database schema.

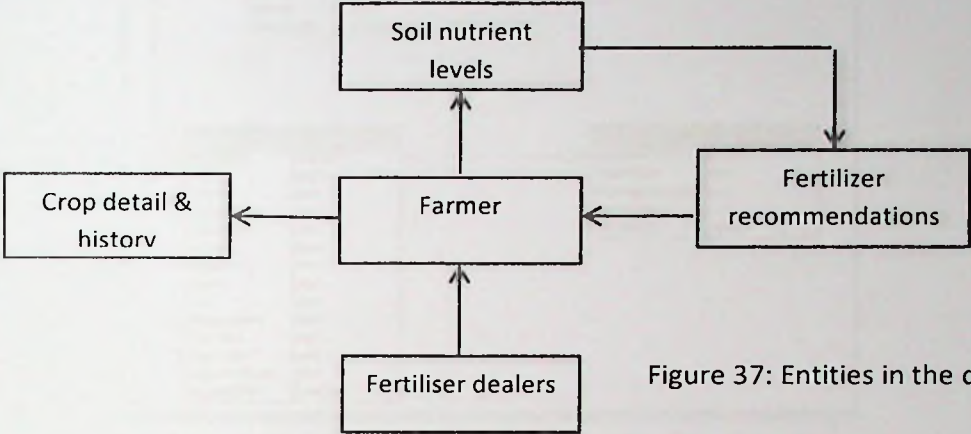


Figure 37: Entities in the database schema

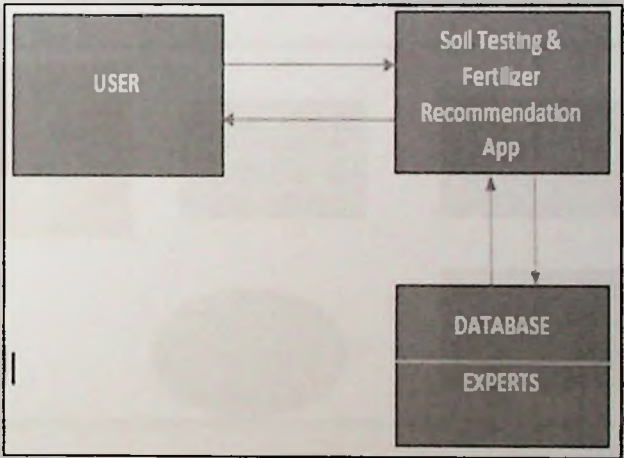


Figure 38 Conceptual diagram

Below is the high level entity relationship diagram that was developed to aid in the database design and to show relationships between the different entities.

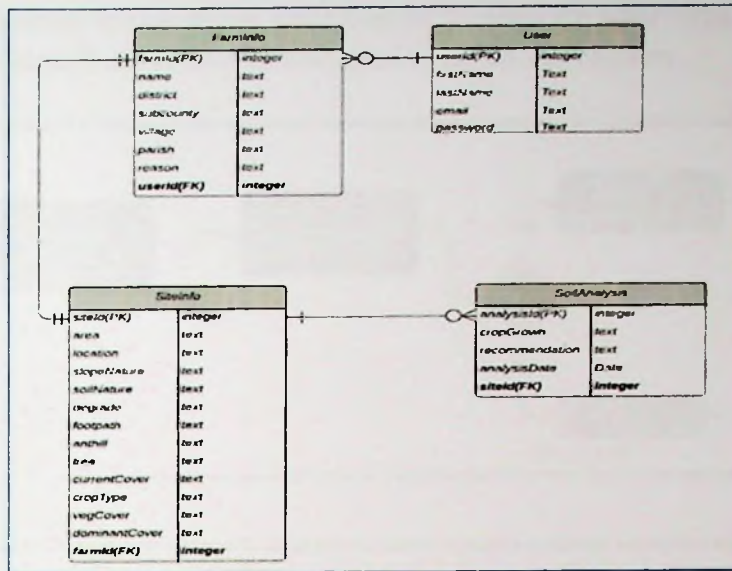


Figure 39 Database Entity Relation Diagram (ERD)

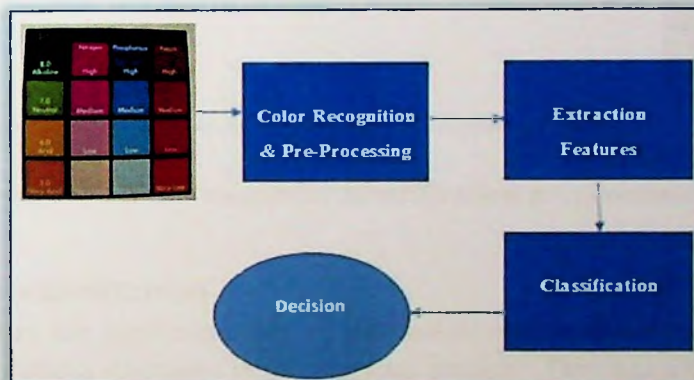


Figure 40 showing the color recognition process

Color Processing (Preprocessing)

The whole process rotates around color identification using Texture update listener in the camera. Once there is a change in pixel contrast, a call back listener is triggered which checks for the closest color match in the saved color data set. The closest match is returned as the result color match. The closest color match is attained after a comparison between saved Laboratory soil nutrient color data set and the color grab universal color wheel/ space (RGB and HSV). A capture request is created; capture session captures and matches the image segment with the

soil fertiliser application values which were carefully coded by color. The color segments are identified by color identification tools as discussed in the earlier chapters.

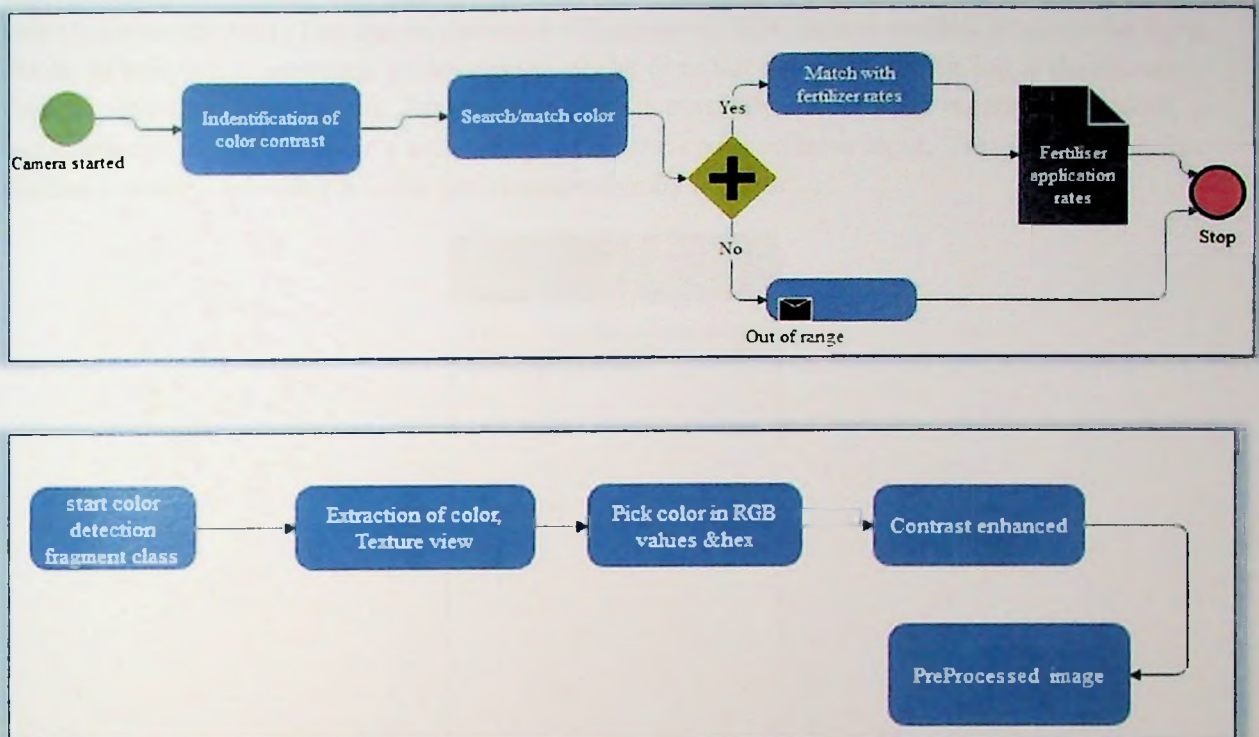


Figure 41: Showing color identification preprocessing

4.5 System Implementation

This section describes the implementation of the mobile application based on the design and requirements specifications discussed in the previous section. This was a big step to be reached in achieving the set specific objective three (3) of the research. The technologies used in implementing the mobile application functionalities were based on ease of use, free licensing information i.e. open source, availability and functionality. These technologies included: Android studio for the development of the application interface, SQLite for the database design java. Throughout the designing and the development process, the waterfall model was followed as indicated in the methodology.

4.5.1 System functionalities and operations

The mobile application has various functions which include capturing of user (farmer) details, crop details, nature of the soil, analyzing of soil nutrients and computation of recommended fertiliser application rates and availing list of available fertiliser suppliers. The various processes

and actions performed with this mobile application were previewed as shown below with their corresponding screenshots attached.

The application has a login page where users of the application will be required to enter their login details. For the new users of the application, registration for an account is mandatory to be able to access the tool. The shared preference function in SQLite was applied. It saves the login details of person i.e. username on his device. So he does not have to enter his log in details every time he opens the application. After a user has successfully entered the registration details, a notification is sent to the user's account to verify the email address input. This is to ensure that the email address provided is valid and is accessible by the user.

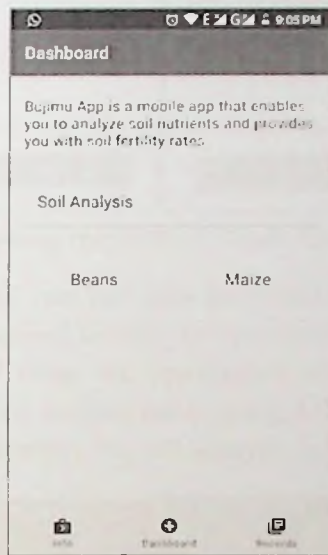


Figure 42 showing the Dashboard tab of the application

One can choose to read the agronomic information concerning beans and maize by clicking the Beans or Maize buttons or go straight to soil analysis.

Once the user has clicked Soil Analysis button, they will be led to next screen where they will have to enter their details as seen in the screen shots below.

Bujimu App

Name

District

Sub County

Parish

Village

GPS LOCATION

Location -1.23 degrees east

Reason for Analysis

SAVE

Bujimu App

Katula Mutyaba

Mukono

Goma

Seeta ward

Kigunga

GPS LOCATION

Location -1.23 degrees east

To know the status of my soil

SAVE

Figure 43 showing registration tab in the application

Once one's credentials are captured, one can now go ahead to interact with the application as follows. After logging in, one is required to enter farmer details and these include; farmer name, district, parish, village, reason for using the application and site characterization. The site location of the farm land is captured automatically using GPS option in the application. With this, it requires one to be in the field where the soil analysis is to be done.

Bujimu App

Site Characteristics

Field area to be sampled

0.5 - 1.0

Location of field along slope

Upper summit

Specify the nature of slope

Gentle slope

Nature of soil

Red with stones

Any signs of degradation

Bujimu App

Farm History

Current cover

Yes

Types of Crop

Perennial crop

Vegetation cover

Yes

Dominant Cover

Commelina bengalensis

SAVE & CONTINUE

Figure 44 Showing site and farm details tab in the application

After capturing the farmer and site information, next is the analysis of the different soil nutrients (NPK, soil PH and organic matter) from the soil sample attained. For each nutrient, it is analyzed

independently and captured by the application in a sequential way. The nutrient levels are computed and made ready for the next step of fertiliser recommendation rates.

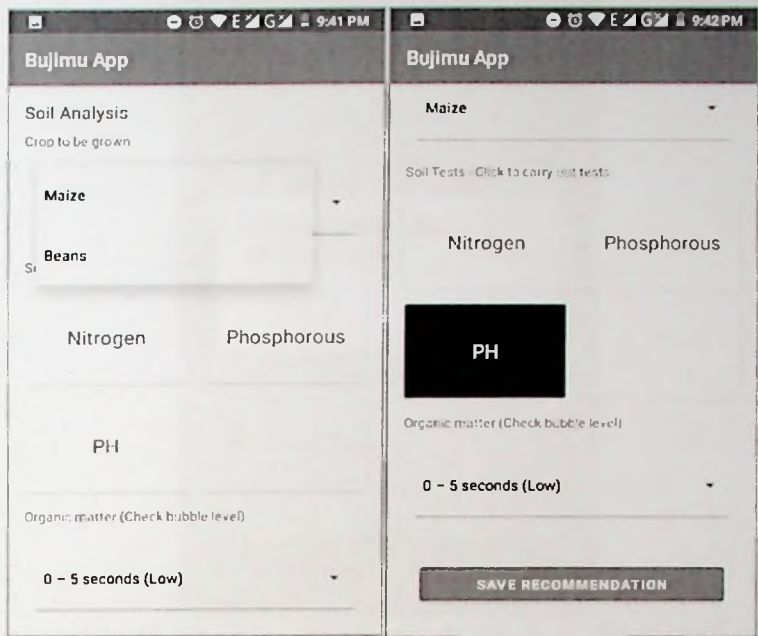


Figure 45 Showing nutrient levels being analyzed by the application

After the soil nutrients available (NPK, soil PH and organic matter) are computed, the results are used to calculate\compute the fertiliser recommendation rate for that particular crop. This is done using the algorithms back coded in the tool.

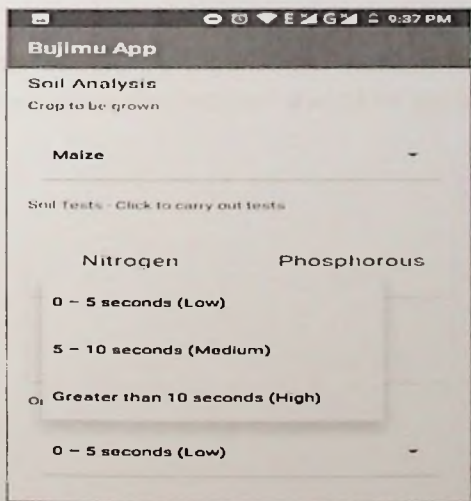


Figure 46 Showing organic matter analysis by the application

Upon completion of the computation process, the results are returned as seen in the display screen below.

Bean Agro Information			Maize Agro Information		
Number of seeds per hole	2		Number of seeds per hole	2	
Spacing	50cm between rows X 10cm within rows		Spacing	75cm between rows X 25cm within rows	
Rainfall needed	350mm - 500mm		Rainfall needed	500mm	
Temperature	15°C - 29.5°C		Temperature	15°C - 29.5°C	
Nature of soil needed	- Deep - Fertile - Loose to tightly compact soils		Nature of soil needed	- Deep - Fertile - Loose to slightly compact soils	
PH needed	5.5 - 6.5		PH needed	5.5 - 6.5	
Fertilizer	Mode of Application	When	Fertilizer	Mode of Application	When
DAP	Basal	Planting	DAP	Basal	Planting
UREA	Top Dressing	45 days	UREA	Top Dressing	45 days
NPK	Top Dressing	45 days	NPK	Top Dressing	45 days
Super Green	Forliar	30 days			
Allwin	Forliar	30 days			

Figure 48 Showing beans and maize agronomic information

Fertiliser suppliers (Info)

A list of fertiliser suppliers, their location, contact and the unit costs of each type of fertiliser is available is availed. This can be accessed from the Info tab.

Suppliers Information		Suppliers Information	
Bukoola Chemicals Limited		NPK	
<u>Available Fertilizers</u>	<u>Unit price @ 50 kg</u>	DAP	120,000 UGX
UREA	150,000 UGX	MCP	100,000 UGX
NPK	150,000 UGX		
DAP	120,000 UGX	Forliar	
MCP	100,000 UGX	<u>Available Fertilizers</u>	<u>Unit price @ 50 kg</u>
		KARA (NPK)	150,000 UGX
		Super Green	120,000 UGX
		Allwin Top	150,000 UGX
Africa One Farmers Shop		Africa One Farmers Shop	
<u>Available Fertilizers</u>	<u>Unit price @ 50 kg</u>	<u>Available Fertilizers</u>	<u>Unit price @ 50 kg</u>
UREA	150,000 UGX	UREA	150,000 UGX
NPK	160,000 UGX	NPK	160,000 UGX
DAP	150,000 UGX	DAP	150,000 UGX
CAN	140,000 UGX	CAN	140,000 UGX

Figure 49 showing a sample of available fertiliser suppliers

Technology experts. A farmer is provided with the crop's general agronomic information and a list of available fertiliser suppliers with their unit costs from which a farmer can purchase the fertiliser. Below is the diagram showing the system process described above.

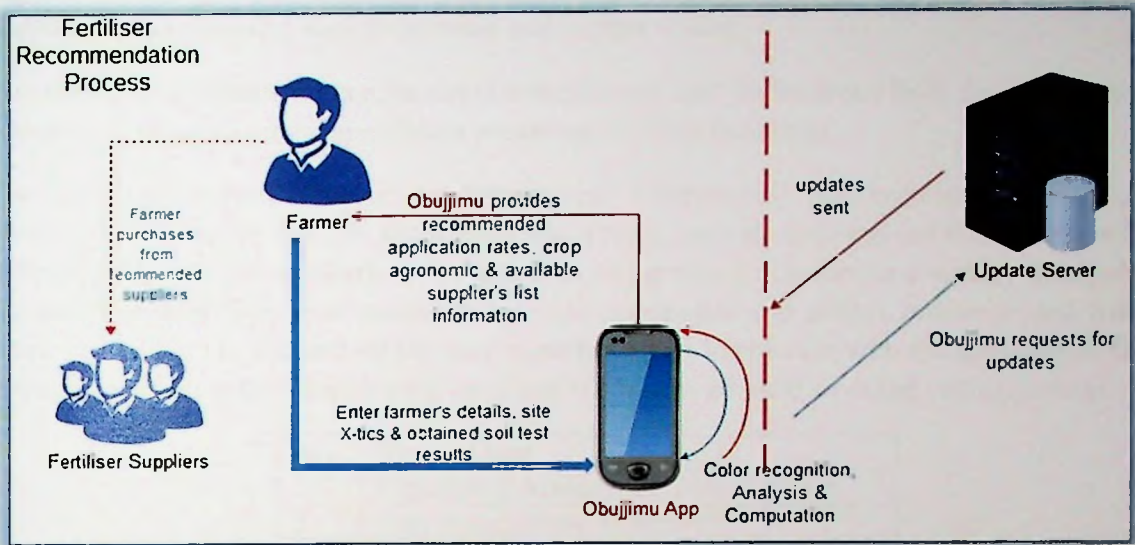


Figure 51: Showing the recommended fertiliser application process

4.5.3 System security

The application system has several layers of security. In order for one to gain access to the application he has to create a username and this verified through his active email address. The application administrator has permission to create users. The tool also maintains an audit trail of all changes made and they are backed up in the Data base (DB) for verification and follow up in case of any security breach.

4.5.4 Testing and Validating

The application system was tested to ensure that the requirements specified by the users especially the farmers and agricultural extension staff were met and prove that the project objective number four (4) was accomplished.

Testing

Testing involved mainly the farmers and extension since they were the main end user and beneficiaries of the tool. Farmers (2) and extension staff (1) carried out the testing of the application. The criteria for selection of the farmers was based on farmers who had attained training on the use of the Makerere soil testing kit, had smart phones of at least 5 mega pixels, those who were very active and readily available during the period. Also for easy of management

and control a small group of people was considered. Resource constraint was also a challenge to the researcher.

In order to make sure that the users understood the application and its operation, a walk-through of the application was conducted before giving them the opportunity to interact with the application and provide feedback. Three test cases were used and these were mainly on the application functionality, user acceptance and system testing.

The testing and validation exercise ran simultaneously and the feedback from users was recorded and used to improve on the application processes and functionalities.

The validation mainly focused on system test (operational) and ensuring reliable system operation. This meant that the application was able to provide deliverables that were needed at different stages in the application. For example, being able to capture user details, being able to upload the soil nutrient tests results, being able to populate and deliver recommended fertiliser rates. The validation focused on the user experience and interaction with the application. Below is the table showing the various tests cases and the results attained from the testing process.

No	Type of test
1	Functional Acceptance Test (FAT)
2	User Acceptance Test(UAT)
3	System Test(ST)

Table 9: Showing the different types of tests

No	Test Case	Test Type	Expected results	Actual Results	Pass/Fail
1	Farmer & site information	UAT	Enter farmer & site information	Farmer & site information captured by the application	Pass
2	Soil nutrient result analysis & interpretation	FAT	Recognize the soil test results for analysis	Soil nutrient test results captured by the application	Pass
3	Recommended fertiliser rates copulation	FAT	Computation of fertiliser application rates	Return recommended fertiliser application rates	Pass
4	Input wrong username & password	ST	Invalid user name & password	Login failed. Username or password invalid	Pass

Table 10: Showing the testing and validation of the application

Test results

User Acceptance Test

- < Farmers noted that the site characteristic and farm history information to be filled were too many and time wasting which needed to be reduced to fewer variables.

This was put into consideration and the following were removed;

Under site characterization they included; any signs of degradation, how many anthills, any footpath, how many big trees.

Those eliminated in the farm history area included; vegetation cover and dominant cover crops.

- < Farmers noted that the login process was long and what was needed like their email addresses, some did not have.

This was taken note of and simplified. One logs in using their name only.

Validation process and results attained

During the process, eight (8) soil samples were run through the three soil testing systems; Laboratory test (chemically), Makerere soil testing kit (reagents) and the mobile application for validation of the results. Four soil nutrients were looked at; Nitrogen, Phosphorous, Potassium, alkalinity (PH) as per the project's requirements as discussed in the methodology.

The validation process was intended to compare the results attained from an expert system i.e. laboratory, Makerere soil testing kit and the mobile application for any deviations and errors in the results attained.

Involved stalk holders during validation

The laboratory technicians at Makerere university laboratory carried out the laboratory tests. The Makerere soil testing kit was used by one soil scientist at NARO for the results attained and the third results using the application was carried out by one farmer under the guidance of the researcher. Below are the results that were attained.

Soil validation results

Sample No	GPS location		Lab test				Makerere soil testing Kit				Mobile App			
	North	East	(%)N	P (ppm)	K (ppm)	PH	(%)N	P (ppm)	K (ppm)	PH	(%) N	(ppm) P	(ppm) K	PH
P1S1	00.38271	032.73397	0.19	15.66	157.44	5.3	0.20	15	188.5	4.5	0.19	14	188.5	4.5
P1S2	00.38237	032.73397	0.17	4.61	83.87	5.1	0.20	14	19	4.5	0.19	14	19	4.5
P2S1	00.38261	032.73349	0.17	3.79	132.28	5.4	0.20	13	18.5	5.0	0.19	13	18.5	5.0
P2S2	00.38243	032.73358	0.17	6.25	145.71	5.2	0.15	14	18.5	4.5	0.15	14	18.5	4.5
P2S3	00.38226	032.73359	0.16	9.79	129.74	5.2	0.20	14	18.5	5.0	0.19	14	18.5	5.0
P3S1	00.38230	032.73334	0.19	5.29	77.94	5.3	0.19	14	18.5	4.5	0.19	14	18.5	4.5
P3S2	00.38263	032.73325	0.18	11.84	100.74	5.2	0.20	14	18.5	4.5	0.19	14	18.5	4.5
P3S3	00.38320	032.73392	0.19	103.48	511.13	6.3	0.19	15	18.5	4.5	0.18	15	18.5	4.5

Table 11: Showing the validation results

Interpretation

(%) = percentage, (ppm) = parts per million,

P =Phosphorous, K= Potassium, PH= Acidity& Alkalinity

- P1S1=Plot1 sample 1
- P1S2= Plot1 sample 2
- P2S1= Plot2 sample 1
- P2S2= Plot2 sample 2
- P2S3= Plot2 sample 3
- P3S1= Plot3 sample 1
- P3S2= Plot3 sample 2
- P3S3= Plot3 sample 3

Soil PH validation Results

Sample No	Lab results	Makerere soil testing Kit results		Bujjimu App results			
	PH value	PH value	Color viewed	PH value	Color code	Color	Fertiliser rates (maize crop)
P1S1	5.3	4.5	Dirty green	4.5	#6D6C28	Crete	Agric Lime= 40kg
P1S2	5.1	4.5	Dirty green	4.5	#286ACD	Marino	Agric Lime= 40kg
P2S1	5.4	5.0	Light blue	5.0	#B7B1B1	Nobel	Agric Lime= 40kg
P2S2	5.2	4.5	Very light green	4.5	#C9B29B	Rodeo	Agric Lime= 40kg
P2S3	5.2	5.0	Light blue	5.0	#D3CBBA	Sisal	Agric Lime= 20kg
P3S1	5.3	4.5	Dirty green	4.5	#6d6c28	Crete	Agric Lime= 40kg
P3S2	5.2	4.5	Green	4.5	#25311C	Green Kelp	Agric Lime= 40kg
P3S3	6.3	4.5	Dirty green	4.5	#8BA690	Envy	Agric Lime= 40kg
Total mean, standard deviation and error							
Total mean	5.375	4.625		4.625			
Standard Deviation	0.384	0.232		0.232			
Standard Error	0.136	0.082		0.082			
Mean +/- SE	5.239 to 5.511	4.543 to 4.707		4.543 to 4.707			
		Acidic		Acidic			

Table 12: Showing Soil PH results

Interpretation of results by standard error

The PH results from the methods of soil analysis (Laboratory, Makerere soil test kit and Bujjimu Application) did not vary much. The standard error was 0.082 for both systems (Makerere soil test kit and Bujjimu Application) which shows the accuracy of the Bujjimu Application. The PH levels attained by the Makerere soil testing kit and the Bujjimu application, ranged between 4.543 to 4.707. With that result, it indicates that the soil samples were acidic and needed application of agricultural lime.

The table also indicates the color observed when using the Makerere soil testing kit and that identified by the Bujjimu application and the fertiliser application rates results.

Interpretation of values by graph

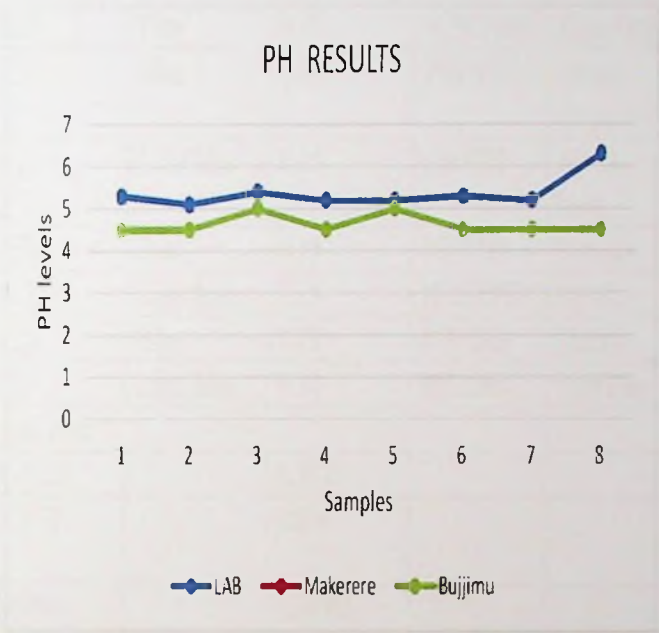


Figure 52 Showing PH values

According to the results, there was no variance in results attained while using the Makerere soil testing kit and the Bujjimu application. The PH levels attained indicate that the soils were acidic.

Nitrogen (N) Results

Sample No	Lab test	Makerere soil testing Kit		Bujjimu App results			
	(%)N	(%)N	Color viewed	(%)N	Color code	Color	Fertiliser rates (maize crop)
P1S1	0.19	0.20	Blue	0.19	#B5D2CE	Jet stream	UREA=20kg, NPK=20kg
P1S2	0.17	0.20	Blue	0.19	#CBCAB6	Fogg Gray	UREA=20kg, NPK=20kg
P2S1	0.17	0.20	Blue	0.19	#9B9E8F	Lemon Grass	UREA=20kg, NPK=20kg
P2S2	0.17	0.15	Light blue	0.15	#948771	Arrow town	UREA=20kg, NPK=20kg
P2S3	0.16	0.20	Blue	0.19	#6E7783	Pale sky	UREA=20kg, NPK=20kg
P3S1	0.19	0.19	Light blue	0.19	#E2EBED	Mystic	UREA=20kg, NPK=20kg
P3S2	0.18	0.20	Blue	0.19	#F6F0E6	Merino	UREA=20kg, NPK=20kg
P3S3	0.19	0.19	Light blue	0.18	#8DA8CC	Polo Blue	UREA=20kg, NPK=20kg
Total mean, standard deviation and error							
Total mean	0.1775	0.19125		0.8375			
Standard Deviation	0.0116	0.0172		0.014			
Standard Error	0.00410	0.00608		0.00495			
Mean+/- SE	0.1734 to 0.1816	0.18517 to 0.19733		0.1788 to 0.1887			
	Medium	Inadequate		Inadequate			

Table 13: Showing Nitrogen results attained

Interpretation of the results by standard error

The Nitrogen results from the methods of soil analysis did not vary much (difference of 0.00113 for the standard error). The standard error for Makerere soil test kit was at 0.00608 and that of the Bujjimu Application was at 0.00495, which shows the accuracy of the Bujjimu Application. With that, there was no much significant difference from both systems (Makerere soil test kit and Bujjimu Application)). From the Nitrogen result attained, it indicated that the soil samples had inadequate Nitrogen and needed application as per the results above.

Interpretation of results by graph

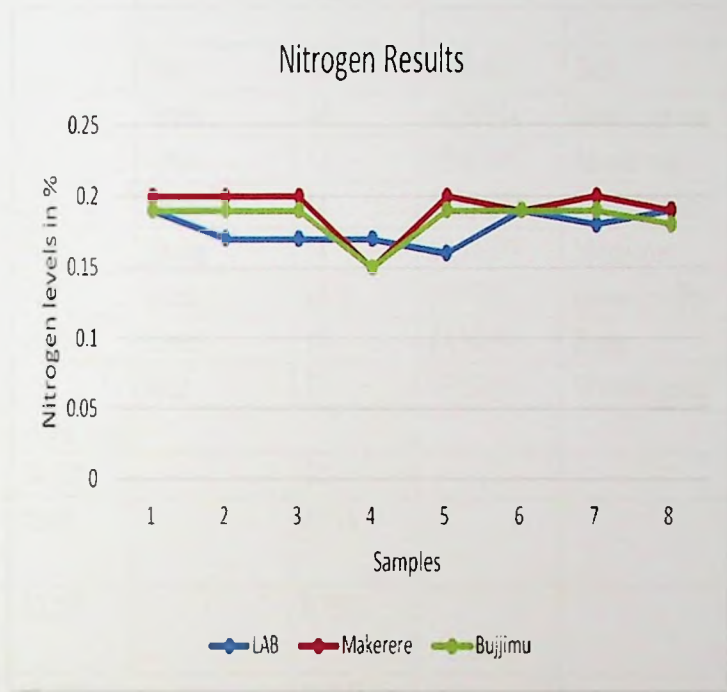


Figure 53: Showing Nitrogen levels

According to the results attained, there was some slight difference of about 0.1% between the Makerere soil testing kit and the Bujjimu application. The Nitrogen levels from the soil samples indicated that they were inadequate.

Phosphorous (P) Results

	Lab Results	Makerere soil testing Kit results		Mobile App Results			
Sample No	P (ppm)	P (ppm)	Color viewed	P (ppm)	Color code	Color	Fertiliser rates results (maize crop)
P1S1	15.66	15	Blue	14	#B19461	Teak	NPK=20kg, DAP=20kg
P1S2	4.61	14	Green	14	#8D8974	Granite green	NPK=20kg, DAP=20kg
P2S1	3.79	13	Green	13	#B4CFD3	Jungle mist	NPK=40kg, DAP=40kg
P2S2	6.25	14	Green	14	#EEFDFF	Twilight blue	NPK=20kg, DAP=20kg
P2S3	9.79	14	Green	14	#B5A27F	Mongoose	NPK=40kg, DAP=40kg
P3S1	5.29	14	Green	14	#795D4C	Roman coffee	NPK=20kg, DAP=20kg
P3S2	11.84	14	Green	14	#A59B91	Zorba	NPK=20kg, DAP=20kg
P3S3	103.48	15	Blue	15	#3F5D53	Mineral green	NPK=0kg, DAP=0kg
Total mean, standard deviation and error							
Total mean	20.089	14.125		14			
Standard Deviation	33.94	0.641		0.534			
Standard Error	12.0014	0.2267		0.1888			
Mean+/- SE	8.0873 to 32.0902	13.8983 to 14.3517		13.8112 to 14.1888			
	Low	Moderate		Moderate			

Figure 54 Showing Phosphorous results attained

Interpretation of the results by standard error

The standard error for the Makerere Soil testing kit attained was 0.2267 and the Bujjimu application was 0.188, there is no much variance. Therefore, the Application returns accurate information as per the soil testing kit. With that, there was no much significant difference from both systems. The results attained indicated that the soil samples had moderate Phosphorous and fertiliser rates can be applied as per the results above.

Interpretation of results by graph

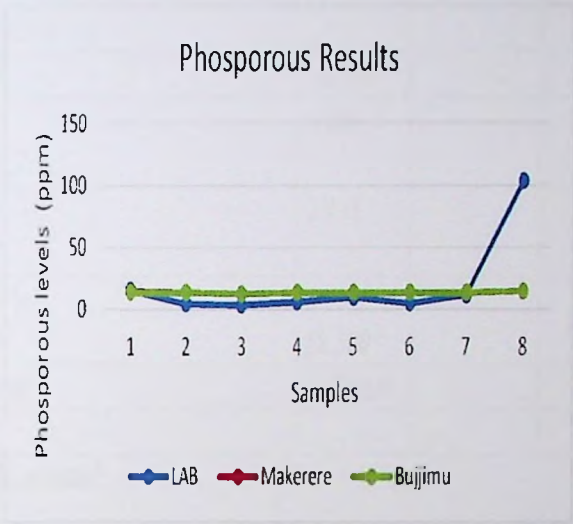


Figure 55 Showing Phosphorous levels

From the graph results, it indicated that the phosphorous levels were moderate. In addition, there was no significant difference between the results attained using the Makerere soil testing kit and the Bujjimu application as indicated by the graph above. There is a slight difference of about 0.0378 ppm less by the Bujjimu application.

Potassium (P) Results

	Lab Results	Makerere soil testing Kit results		Mobile App Results			
Sample No	K (ppm)	K (ppm)	Color viewed	K (ppm)	Color code	Color	Fertiliser rates results (maize crop)
P1S1	257.44	58.5	Cloudy yellowish	58.5	#F8E4BF	Givry	NPK=0kg
P1S2	83.87	39	Slightly cloudy yellowish	39	#C9B29B	Radeo Dust	NPK=40kg
P2S1	132.28	58.5	Cloudy yellowish	58.5	#E7BCB4	Rose Fog	NPK=0kg
P2S2	143.71	58.5	Cloudy yellowish	58.5	#D1C6B4	Soft amber	NPK=0kg

P2S3	329.74	58.5	Cloudy yellowish	58.5	#D4C4A8	Akoroa	NPK=0kg
P3S1	272.94	58.5	Cloudy yellowish	58.5	#F8E4BF	Givry	NPK=0kg
P3S2	160.74	58.5	Cloudy yellowish	58.5	#FAECCC	Champaign	NPK=0kg
P3S3	531.13	58.5	Cloudy yellowish	58.5	#F5E9D3	Albescent white	NPK=0kg
Total mean, standard deviation and error							
Total mean	238.981	56.063		56.063			
Standard Deviation	144.283	6.894		6.894			
Standard Error(SE)	51.019	2.438		2.438			
Mean+/- SE	187.962 to 290.001	53.625 to 58.500		53.625 to 58.500			
	High	sufficient		sufficient			

Figure 56 Showing Potassium results attained

Interpretation of the results by standard error

The Potassium results from the methods of soil analysis did not vary much. The standard error for both the Makerere soil test kit and Bujjimu Application was at 2.438, which shows the accuracy of the Bujjimu Application. With that, there was no much significant difference from both systems. From the Potassium results attained, it indicated that the soil samples had sufficient Potassium.

Representation of results by graph

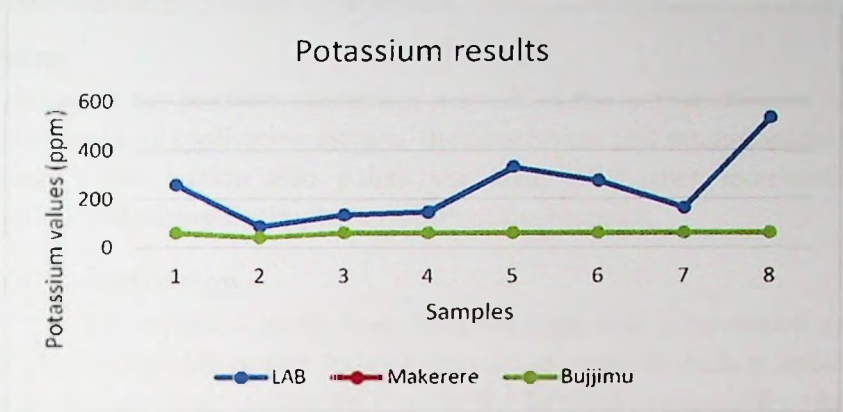


Figure 57 Showing Potassium levels

According to the graph, there is no much difference in the results attained using the Makerere soil testing kit and the Bujjimu application. In addition, the potassium levels were found sufficient.

Conclusion:

The results for Potassium analysis are kind of in linear output simply because we are looking at only two variables i.e. presence of Potassium and no potassium.

The variance in the results especially when using the Bujjimu application is attributed mainly to two aspects i.e. light pollution during process of color identification and difference in camera pixels of the phones used. The higher the phone pixels the better the resolution.

In addition, to note is that some results may look a little variant but this is due to the different extraction methods used especially for the laboratory results but the meaning is the same. Case in point can be the extraction method of soil PH; it can be either by Hydrochloric acid or by distilled water. The results can look different but the interpretation is the same. The validation process went on well in that the Bujjimu application was validated against the Makerere soil testing kit and the laboratory test and the results discussed as seen above. The Application was able to analyze soil nutrient values, identify soil nutrient color and avail appropriate soil fertiliser application rates. The results attained did not have any significant variations as seen above.

Chapter Five

5.0 Conclusion and Recommendation

5.1 Conclusion

This chapter discusses the possible changes as a result of the introduction of the recommended fertiliser application rates application system, the conclusion and recommendation based on the research findings. This section also points out areas of further intervention/research and challenges encountered during the implementation of the research.

5.2 Research Contribution

The research project contributed to the body of knowledge and Information availability in the agricultural sector through innovative technologies using Android mobile application (ICTs) to deliver recommended fertiliser application rates to the farming communities (farmers, extension staff and others), focusing its analysis largely on soil nutrients composition and use of mobile phone technology which has become more widely used of recent as a means of disseminating agricultural information to farmers and various agricultural entrepreneurship. The area of focus was mainly agricultural information (recommended fertiliser application rates and available suppliers of the fertilisers) dissemination for improved agricultural yields and increase income of farmers.

The process model (especially for attaining the different soil nutrients), the database design and the subsequent documentation of the system requirements and specifications contributed to the study areas business process modeling.

The development of the fertiliser rates recommendation mobile application would subsequently aid in improving turnaround time for delivery and attaining of recommended fertiliser application rates by farmers. This smart environmental choice allows growers to save money and increase yields, by using the right rate and type of fertilizers. The solution also addresses the global misuse of fertilizers that results in waste, soil damage, and groundwater contamination. It also enhances fertiliser management through provision of timely information concerning correct timing, placement and methods of fertiliser application and right source of fertiliser in order to maximize nutrient uptake and yield targets.

5.3 Challenges

There were challenges encountered during the implementation of the research. Some of these challenges included the limited literature on recommended fertiliser application rates systems especially of this nature. This could be associated with the fact that most implementations of similar projects were implemented as in house projects with limited documentation accessible to the public. Data on fertiliser prices in Uganda is still a challenge. Then also the number of households applying fertilisers in Uganda is not available to enable the computation of fertiliser usage in Uganda.

5.4 Opportunities and lessons Learnt

Over the period in which the research was conducted, there was extensive exposure in the various areas of study under the Management Information systems program in practice. That is application development, Research Methodology, Database Management, Information Security, System analysis and Design, Business Process Modeling, Information system for managers, Enterprise Architecture to mention but a few. This experience gave the researcher a broader understanding of the course content and appreciation of the principals learnt over the two years.

The mobile application technology presents an opportunity where geographical location will not be a hindering factor and also reduce on the production costs especially as it had been on the extension staff. The farmers or anyone in need of recommended fertiliser application rates will be in better position to manage this service more efficiently and improve on decision making with the information at their disposal.

The use of this mobile application will reduce greatly on the time that has been taken to attain the soil nutrients results; of four (4) to five (5) days at Makerere University College of Agriculture and Environmental Sciences (CAES) and National Agricultural Research's Laboratory (NaRL) at Kawanda to just hours (at most 1 hour).

5.5 Conclusion

The research set out to develop a mobile application as a means to interpret, analyze and provide easily recommended fertiliser application rates to farmers of selected crops (beans and maize) since it had been a costly aspect to farmers and agricultural entrepreneurs in Uganda. Based on the results discussed in the prior chapter, this was achieved by breaking down the major objectives into specific objectives that included; identifying the requirements needed to develop a mobile application, designing the mobile application's processes, functions and structure, implementing/developing the mobile application, validating and testing of the mobile application to readily avail information to the agricultural communities hence improvement on agricultural yield, reduction on production costs and time saving. This mobile application provides advisory services to the farmers at quickest time. This service delivery channel is outstanding with its effectiveness in decision making.

5.6 Areas of further research intervention

An area of further intervention identified by the researcher is to integrate the recommended fertiliser application system with an online business portal or database to enable farmers purchase the fertilisers on line from the available suppliers and have it delivered. Another area of intervention would be calibrating of more soil samples in the laboratory in order to have a wider range of variables as this could not be covered by the researcher due to resource constraints.

5.7 Recommendations

The researcher recommends the use of the Bujjimu mobile application in order to improve on fertiliser application decision making, reduce on resource wastage especially time, ground water contamination due to over dosage of the soil and getting the right fertiliser recommended rates. The researcher would encourage farmers to embrace the use of ICT since it enables precise agriculture were by the “Bujjimu” mobile application is one of them. If used on a large scale, it would benefit the farmers in terms of increased crop production. The application is user friendly so everyone can use it. Service delivery channels are versatile from where people get different types of contemporary services. Fertilizer recommendation services could be extended with a vision to help the rural farmers and general people to access relevant and required information.

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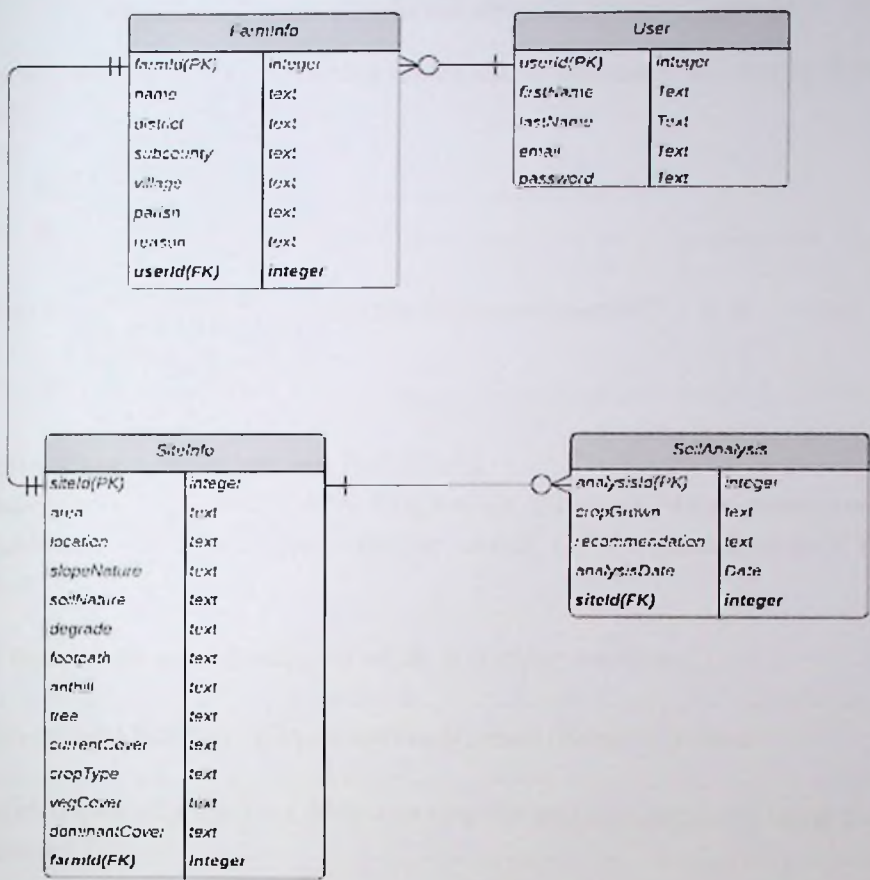
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Web site materials

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APPENDICES

1. Database tables



- A. Farmer details
- B. Crop details and soil history
- C. Soil nutrient levels

2. Interview guide

Interview guide for the investigation of the research problem and requirements determination for the development of a mobile application for recommended fertiliser application rates of selected crops in central Uganda.

1. Have you ever attained any training on the use of Makerere soil testing kit to get nutrient levels? Yes No
If yes;
 < How many times?
 < By who/ which organization?
2. Do you carry out soil testing using the Makerere yourself? Yes No
If No;
 ❖ Why?
3. Which soil nutrients do you test for? (Tick)
 Primary (NPK), **Secondary** (CA, Magnesium, Sulphur), **Micro nutrients** (Iron, manganese, boron, zinc, copper, chlorine, cobalt, molybdenum & nickel), **PH**, **Organic carbon**
4. Give three major annual crops on which you apply fertilisers?
 1.....2.....3.....
5. Which mineral fertilisers do you commonly use? (Name top three)
 1.....2.....3.....
6. What challenges do you face while carrying out soil nutrients tests using the Makerere soil testing kit?

7. Where do you get the recommended fertiliser application rates from?
 ☐ Extension staff ☐ Fertiliser manuals ☐ Fellow farmers ☐ Radios
8. What challenges do you face while getting recommended fertiliser application rates?

9. What information would you want a mobile application to provide to you concerning soil nutrient levels?

10. What information would you want a mobile application to provide to you concerning fertiliser application rates?

11. How can the soil testing process be improved upon or made easier?

3. Profile and roles of stakeholders involved

No	Stakeholders	Role played in the fertiliser usage system
1	Farmers	User of the soil testing kit & users of the fertilisers
2	Extension staff	Identification of farmers, provide recommended fertiliser application rates
3	Soil scientists	Develop fertiliser application combination and rates
4	IT specialists	Developed algorithms and application systems

Soil scientists

They provided technical support to the researcher in the area of elementary soil fertility, soil nutrition, soil testing and recommended fertiliser application rates processing.

Professor Tenywa Moses

College of Agriculture and Environmental sciences Makerere University

Email:tenywamakooma@yahoo.com

Tel: +256701 827710

Dr. Opolot

Head Soil science departments

College of Agriculture and Environmental sciences Makerere University

Email: eopolot@caes.mak.ac.ug

opolot@yahoo.com

Dr. Olupot Ebanyat

Soil Science Laboratory In charge

College of Agriculture and Environmental sciences Makerere University

Ms. Gorret Aguttu

Soil laboratory Technician

College of Agriculture and Environmental sciences Makerere University

Email: aguttugorret@gmail.com

National Agricultural research Organization (NARO)

Ms. Teddy Kizza

Soil and water fertility scientist

National agricultural Research Organization

Email: ktlmartina2009@gmail.com

teddy.kizza@naro.go.ug

Tel: +256 784306605

Mr. Julius Opio

Soil Scientist

National agricultural Research Organization

Email: juliusopio1717@gmail.com
Tel: +256 773 820551

Soil testing kit and Soil Fertility manual developer

This was the team behind the development of the Makerere soil testing kit and soil fertility testing manual.

1. Mr. Stephen Katende Serunjogi
Soil laboratory Technician
College of Agriculture and Environmental sciences Makerere University
2. Mr. Kizza Luswata
Email: kizluswata@agric.mak.ac.ug

Extension staff

These participated in the identification of relevant farmers who had been trained in soil testing. They also provided information on how they supported the farmers through the whole process of soil testing and attaining of recommended fertiliser application rates.

Mr. Mawejje Herbert
Soil scientist (extension staff)
Email: mawejjeharbert@gmail.com

Mr. Biso Godfrey
Extension staff, Goma division Mukono
Email: godbiso2@gmail.com

Farmers

Users of the mobile application. They participated in the identification of requirements and testing of the application. Below are the lead/contact farmers used to mobile others.

Mr. Kituuka George
Ms. Nakivumbi Esther

IT specialists

Provided support and technical advice in the development, testing of the algorithms and color processing in the mobile application. They provided technical back stopping in the development of the mobile application.

Mr. Fahad Makabugo
Application developer
Email: f.faragha@gmail.com

4. Project budget estimates

No	Activity	Quantity	Unit Cost	Total Cost
1	Questionnaire printing	120	1000/=	120,000/=
2	Field visit (Wakiso & Mukono)	2	100,000/=	200,000/=
3	Farmer facilitation	120	5,000/=	600,000/=
4	Extension staff facilitation	5	20,000/=	100,000/=
5	Scientist facilitation	2	50,000/=	100,000/=
6	IT support (Data and others)	1	500,000/=	500,000/=
7	Soil Testing Kit (reagents)	1	100,000/=	100,000/=
8	Laboratory fee (Soil lab)	25	25,000/=	625,000/=
9	Printing of project materials (copies of report)	10	15,000/=	150,000/=
10	Transport during project implementation	1	500,000/=	500,000/=
GRAND TOTAL				
				2,995,000/=

5. Testing and validation template

Test date	
Test Type	User Acceptance Test (UAT), Functional Acceptance Test (FAT), System Test(ST)

No	Test Case	Test Type	Expected results	Actual Results	Pass/Fail
1	Register account	UAT	Username		
2	Farmer & site information	UAT	Enter farmer & site information		
3	Soil nutrient result analysis & interpretation	FAT	Capture the soil test results for analysis		
4	Recommended fertiliser rates copulation	FAT	Computation of fertiliser application rates		
5	Input wrong username & password	ST	Invalid user name & password		
6	Bulk users	ST	Many users login at the same time		
	COMMENTS				

Test By		Sign;	
Verified By		Sign;	

6. Pseudo code for the nutrient values using structured English model

Beans

DAP.....40 KG @Acre

NPK.....40KG @Acre

UREA.....20KG @ Acre

Lime.....40KG @ Acre

Nitrogen test

If

Color detected is Dark blue (Adequate) color codes, values (0.20-0.29, 0.29-5.0 and >6)

Then Apply

UREA=0 KG

NPK=0 KG

Else If

Color detected is light blue (Inadequate) color codes, values (0.1-0.19)

Then Apply

UREA= 10 KG

NPK=20 KG

Else If

No color is detected (No color change) color codes, values (<0.1)

Then Apply

UREA= 20 KG

NPK=40 KG

End If

Phosphorous

If

Color detected is Deep blue (High) color codes, values (15-20 and >20)

Then Apply

NPK=0 KG

DAP= 0 KG

Else If

Color detected is light blue (adequate) color codes, values (15)

Then Apply

NPK=20 KG

DAP=20 KG

Else If

Color detected is green (moderate) color codes, values (12-14)

Then Apply

NPK=20 KG

DAP=20 KG

Else If

No color is detected, No color change (very low) color codes, values (<5, 5-8 and 9-11)

Then Apply
NPK=40 KG
DAP=40 KG
End If

Potassium

If
Color detected is cloudy yellow (sufficient), color codes, values (>58.5)
Then Apply
NPK=0 KG
Else If
No color is detected, No color change (inadequate), color codes, values (<39)
Then Apply
NPK=40 KG
End If

PH

If
Color detected is Brown (Acidic), color codes, values (<5)
Then Apply
Agricultural lime = 40 KG
Else If
Color detected is purple (neutral), color codes, values (>6)
Then Apply
Agricultural lime = 0 KG
End If

Organic matter

Reaction.....0-5 secondslow
.....5-10 seconds.....medium
.....10 seconds.....High

Maize

DAP.....40KG @ Acre
UREA.....40KG@ Acre
NPK.....40KG@ Acre
Lime.....40KG @ Acre

Nitrogen test

If
 Color detected is Dark blue (Adequate) color codes, values (0.20-0.29, 0.29-5.0 and >6)
Then Apply
 UREA=0 KG
 NPK=0 KG
Else If
 Color detected is light blue (Inadequate) color codes, values (0.1-0.19)
Then Apply
 UREA= 20 KG
 NPK=20 KG
Else If
 No color is detected (No color change) color codes, values (<0.1)
Then Apply
 UREA= 40 KG
 NPK=40 KG
End If

Phosphorous

If
 Color detected is Deep blue (High) color codes, values; 15-20 and >20
Then Apply
 NPK=0 KG
 DAP= 0 KG
Else If
 Color detected is light blue (adequate) color codes, values (15)
Then Apply
 NPK=20 KG
 DAP=20 KG
Else If
 Color detected is green (moderate) color codes, values (12-14)
Then Apply
 NPK=20 KG
 DAP=20 KG
Else If
 No color is detected, No color change (very low) color codes, values (<5, 5-8 and 9-11)
Then Apply

NPK=40 KG
DAP=40 KG
End If

Potassium

If
 Color detected is cloudy yellow (sufficient), color codes, values (>58.5)
Then Apply
 NPK=0 KG
Else If
 No color is detected, No color change (Inadequate), color codes, values (<39)
Then Apply
 NPK=40 KG
End If

PH

If
 Color detected is Brown (Acidic), color codes, values (<5)
Then Apply
 Agricultural lime = 40 KG
Else If
 Color detected is purple (neutral), color codes, values (>6)
 Then Apply
 Agricultural lime = 0 KG
End If

Organic matter

Reaction.....0-5 secondslow
 5-10 seconds.....medium
 10 seconds.....High

7. Common basic fertilizer materials used for blending and their nutrient content

Material	Analysis	N (%)	P ₂ O ₅ (%)	K ₂ O (%)
Ammonium nitrate	33-0-0	33	0	0
Ammonium sulfate*	21-0-0-24S	21	0	0
Diammonium phosphate	18-46-0	18	46	0
Potassium chloride (muriate of potash)	0-0-60	0	0	60
Potassium sulfate**	0-0-50-16S	0	0	50
Potassium magnesium sulfate***	0-0-22-23S-11Mg	0	0	22
Triple super phosphate	0-46-0	0	46	0
Urea	46-0-0	46	0	0

Common basic fertilizer materials used for blending and their nutrient contents (*Soil testing manual, Agricultural Innovations Systems Brokerages Association & NARO*)

8. Soil nutrients testing color codes

Nitrogen color codes

Adequate Nitrogen	Inadequate Nitrogen	Lack of Nitrogen
Color: Lochmara (Blue) #3766A9 RGB: (55,102,169) HSV: (215°, 67%, 66%)	Color: Wild Blue Yonder (Blue) #7391BF RGB: (115,145,191) HSV: (216°, 39%, 74%)	Color: Grey 90% (White) #E2E6EB RGB: (226,230,235) HSV: (213°, 3%, 92%)
Color: Danube (Blue) #5090CB RGB: (80,144,203) HSV: (208°, 60%, 79%)	Color: Chetwode Blue (Blue) #657EB0 RGB: (101,126,176) HSV: (220°, 42%, 69%)	Color: Link Water (Very light Blue) #C1CFDA RGB: (193,207,218) HSV: (206°, 11%, 85%)
Color: Facebook Blue (Blue) #3B6496 RGB: (59,100,150) HSV: (212°, 60%, 58%)	Color: Havelock Blue (Blue) #527BB8 RGB: (82,123,184) HSV: (215°, 55%, 72%)	Color: Bali Hai (Blue) #7C94AD RGB: (124,148,173) HSV: (210°, 28%, 67%)
Color: Curious Blue (Blue) #4182BA RGB: (65,130,186) HSV: (207°, 65%, 72%)	Color: San Marino (Blue) #4B71AA RGB: (75,113,170) HSV: (216°, 55%, 66%)	Color: Regent St Blue (Cyan:Blue) #8FC2D5 RGB: (143,194,213) HSV: (196°, 32%, 83%)
Color: Picton Blue (Blue) #6196CC RGB: (97,150,204) HSV: (210°, 52%, 80%)	Color: Echo Blue (Light Blue) #A1B5CF RGB: (161,181,207) HSV: (213°, 22%, 81%)	Color: Powder Blue (Very light Cyan: Blue) #B7E0E8 RGB: (183,224,232) HSV: (189°, 21%, 90%)
Color: San Marino (Blue) #5C76A4 RGB: (92,118,164) HSV: (218°, 43%, 64%)	Color: Rock Blue (Faded Blue) #96A1B9 RGB: (150,161,185) HSV: (221°, 18%, 72%)	Color: Linen (White → Yellow: Orange) #F7F3E5 RGB: (247,243,229) HSV: (46°, 7%, 96%)
Color: Mariner (Blue) #4068AF RGB: (64,104,175) HSV: (218°, 63%, 68%)	Color: Logan (Faded Blue) #959CB3 RGB: (149,156,179) HSV: (226°, 16%, 70%)	Color: Grey 90% (White) #F9F1F1 RGB: (249,241,241) HSV: (0°, 3%, 97%)
Color: Chambray (Blue: Violet) #515882 RGB: (81,88,130) HSV: (231°, 37%, 50%)	Color: Onahau (Very light Blue) #BFD8EC RGB: (191,219,236) HSV: (202°, 19%, 92%)	Color: Hint Of Red (White → Red: Orange) #F6ECE9
	Color: Polo Blue (Blue)	

Color: Resolution Blue (Dark Blue) #293D74 RGB: (41,61,116) HSV: (224°, 64%, 45%)	#88B1D6 RGB: (136,177,214) HSV: (208°, 36%, 83%) Color: Steel Blue (Blue) #4175B3 RGB: (65,117,179) HSV: (212°, 63%, 70%)	RGB: (246,236,233) HSV: (13°, 5%, 96%) Color: Hint Of Red (White → Red: Orange) #F6ECE9 RGB: (246,236,233) HSV: (13°, 5%, 96%)
Color: Deep Koamaru (Dark Blue) #1F2F6B RGB: (31,47,107) HSV: (227°, 71%, 41%)	Color: Malibu (Blue) #51B8EC RGB: (81,184,236) HSV: (200°, 65%, 92%)	Color: Pavlova (Brown: Orange) #BDA389 RGB: (189,163,137) HSV: (30°, 27%, 74%)
Color: Resolution Blue (Dark Blue) #1E3174 RGB: (30,49,116) HSV: (226°, 74%, 45%)	Color: Jordy Blue (Blue) #79A7D2 RGB: (121,167,210) HSV: (208°, 42%, 82%)	Color: Mongoose (Faded Brown: Orange) #A78C74 RGB: (167,140,116) HSV: (28°, 30%, 65%)
Color: Wild Blue Yonder (Blue) #7484C8 RGB: (116,132,200) HSV: (228°, 42%, 78%)	Color: Shakespeare (Blue) #6A93C0 RGB: (106,147,192) HSV: (211°, 44%, 75%)	Color: Sandrift (Brown: Orange) #AA8F78 RGB: (170,143,120) HSV: (27°, 29%, 66%)
Color: Mariner (Blue) #4561AC RGB: (69,97,172) HSV: (223°, 59%, 67%)	Color: Summer Sky (Cyan:Blue) #20AAEB RGB: (32,170,235) HSV: (199°, 86%, 92%)	Color: Pale Cornflower Blue (Very light Blue) #AED8F7 RGB: (174,216,247) HSV: (205°, 29%, 96%)
Color: Danube (Blue) #6586C9 RGB: (101,134,201) HSV: (220°, 49%, 78%)	Color: Maya Blue (Light Blue) #7ACBF5 RGB: (122,203,245) HSV: (200°, 50%, 96%)	Color: Echo Blue (Light Blue) #9DB9D7 RGB: (157,185,215) HSV: (211°, 26%, 84%)
Color: Scampi (Blue: Violet) #615F99 RGB: (97,95,153) HSV: (242°, 37%, 60%)		Color: Grey 70% (Light Grey) #BFBEC3 RGB: (191,190,195) HSV: (251°, 2%, 76%)
Color: Jacksons Purple (Blue: Violet) #384180 RGB: (56,65,128) HSV: (232°, 56%, 50%)		Color: Malta (Faded Brown: Orange) #AB9687 RGB: (171,150,135) HSV: (25°, 21%, 67%)
Color: Deep Koamaru (Dark		

Blue: Violet) #2A3069 RGB: (42,48,105) HSV: (234°, 60%, 41%) Color: San Marino (Blue) #546AA0 RGB: (84,106,160) HSV: (222°, 47%, 62%) Color: Chetwode Blue (Blue) #5B75A9 RGB: (91,117,169) HSV: (220°, 46%, 66%) Color: Jacksons Purple (Blue) #3C487F RGB: (60,72,127) HSV: (229°, 52%, 49%) Color: Victoria (Blue: Violet) #495084 RGB: (73,80,132) HSV: (232°, 44%, 51%) Color: Facebook Blue (Blue) #3F5A9B RGB: (63,90,155) HSV: (222°, 59%, 60%) Color: Resolution Blue (Dark Blue) #203D83 RGB: (32,61,131) HSV: (222°, 75%, 51%) Color: Egyptian Blue (Dark Blue) #164695 RGB: (22,70,149) HSV: (217°, 85%, 58%)		Color: Silk (Faded Brown: Orange) #BFA89B RGB: (191,168,155) HSV: (21°, 18%, 74%) Color: Del Rio (Faded Brown: Orange) #B9A291 RGB: (185,162,145) HSV: (25°, 21%, 72%) Color: Martini (Grey → Red: Orange) #B9A5A0 RGB: (185,165,160) HSV: (12°, 13%, 72%) Color: Grain Brown (Light Brown: Yellow) #CBBD9F RGB: (203,189,159) HSV: (40°, 21%, 79%) Color: Bronco (Faded Brown: Orange) #AD9783 RGB: (173,151,131) HSV: (28°, 24%, 67%) Color: Cold Turkey (Light faded Brown: Orange) #CCBBAF RGB: (204,187,175) HSV: (24°, 14%, 80%) Color: Nobel (Grey → Violet: Pink) #AC99A4 RGB: (172,153,164) HSV: (325°, 11%, 67%) Color: Spun Pearl (Grey → Violet) #A69CAA RGB: (166,156,170)
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Phosphorous color codes

High Phosphorous	Adequate and Moderate Phosphorus	N
Color: Grey 30% (Dark Grey) #4D454E RGB: (77,69,78) HSV: (293°, 11%, 30%)	Color: Logan inadequate p (Grey → Blue) #9EA3B3 RGB: (158,163,179) HSV: (225°, 11%, 70%)	C
Color: Grey 30% (Dark Grey) #4D454E RGB: (77,69,78) HSV: (293°, 11%, 30%)	Color: Heather (Light Grey → Blue) #B0B5C1 RGB: (176,181,193) HSV: (222°, 8%, 75%)	# R H
Color: Grape (Dark faded Blue: Violet) #3D3A52 RGB: (61,58,82) HSV: (247°, 29%, 32%)	Color: Heather (Light Grey → Blue) #B3BBC6 RGB: (179,187,198) HSV: (214°, 9%, 77%)	C Y # R H
Color: Black Russian (Black → Violet) #20182E RGB: (32,24,46) HSV: (261°, 47%, 18%)	Color: Link Water (Light faded Blue) #C0CAD5 RGB: (192,202,213) HSV: (211°, 9%, 83%)	C R # R H

Color: Mulled Wine (Dark Grey → Blue: Violet) #524B63 RGB: (82,75,99) HSV: (257°, 24%, 38%) Color: Bunting (Dark Blue: Violet) #2E2D49 RGB: (46,45,73) HSV: (242°, 38%, 28%) Color: Bay Of Many (Dark Blue: Violet) #394063 RGB: (57,64,99) HSV: (230°, 42%, 38%) Color: Kimberly (Faded Blue: Violet) #65678D RGB: (101,103,141) HSV: (237°, 28%, 55%) Color: Chambray (Faded Blue: Violet) #535A7D RGB: (83,90,125) HSV: (230°, 33%, 49%) Color: Comet (Grey → Blue: Violet) #5A5D7B RGB: (90,93,123) HSV: (234°, 26%, 48%) Color: East Bay (Faded Blue) #4C5373 RGB: (76,83,115) HSV: (229°, 33%, 45%) Color: Smoky (Grey → Blue: Violet) #555873 RGB: (85,88,115)	Color: Casper (Light Grey → Blue) #A8B0BE RGB: (168,176,190) HSV: (218°, 11%, 74%) Color: Heather (Light Grey → Blue) #B0B5C3 RGB: (176,181,195) HSV: (224°, 9%, 76%) Color: Periwinkle (Very light Blue) #C1D1E3 RGB: (193,209,227) HSV: (211°, 14%, 89%) Color: Echo Blue (Light Blue) #A5B3C8 RGB: (165,179,200) HSV: (216°, 17%, 78%) Color: Lavender (White → Blue) #DEECF6 RGB: (222,236,246) HSV: (205°, 9%, 96%) Color: Heather (Light faded Blue) #ACB6C7 RGB: (172,182,199) HSV: (217°, 13%, 78%) Color: Echo Blue (Light faded Blue) #A1AEC1 RGB: (161,174,193) HSV: (215°, 16%, 75%) Color: Echo Blue (Light Blue) #A5B8D2 RGB: (165,184,210) HSV: (214°, 21%, 82%) Color: Echo Blue (Light Blue) #A4B6CE	Color: White (White) #FFFDF4 RGB: (255,253,244) HSV: (49°, 4%, 100%) Color: Derby (White → Orange) #F9E1CD RGB: (249,225,205) HSV: (27°, 17%, 97%) Color: Blanched Almond (White → Orange) #FEE5CE RGB: (254,229,206) HSV: (28°, 18%, 99%) Color: White (White) #FFF7F2 RGB: (255,247,242) HSV: (23°, 5%, 100%) Color: White (White) #FBF4F1 RGB: (251,244,241) HSV: (18°, 3%, 98%) Color: Spicy Mix (Brown:Orange) #886253 RGB: (136,98,83) HSV: (16°, 38%, 53%) Color: Medium Wood (Brown:Orange) #B48566 RGB: (180,133,102) HSV: (23°, 43%, 70%) Color: Sandrift (Brown:Orange) #B39080 RGB: (179,144,128) HSV: (18°, 28%, 70%) Color: Eunry (Light Brown:Orange) #CAAD9E RGB: (202,173,158)
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HSV: (234°, 26%, 45%) Color: Logan (Grey → Blue) #9AA5B2 RGB: (154,165,178) HSV: (212°, 13%, 69%) Color: Black Pearl (Black → Blue: Violet) #140E26 RGB: (20,14,38) HSV: (255°, 63%, 14%) Color: Toloopa (Dark Blue: Violet) #2A2345 RGB: (42,35,69) HSV: (252°, 49%, 27%) Color: East Side (Faded Violet) #A797BC RGB: (167,151,188) HSV: (265°, 19%, 73%) Color: Deluge (Grey → Blue: Violet) #7E7595 RGB: (126,117,149) HSV: (256°, 21%, 58%) Color: Fedora (Dark faded Violet) #5E4966 RGB: (94,73,102) HSV: (283°, 28%, 40%) Color: Fedora (Faded Violet) #614B6A RGB: (97,75,106) HSV: (282°, 29%, 41%) Color: Black Russian (Black → Violet) #1E102A RGB: (30,16,42)	RGB: (164,182,206) HSV: (214°, 20%, 80%) Color: Periwinkle (Very light Blue) #C5D7E8 RGB: (197,215,232) HSV: (209°, 15%, 90%) Color: Periwinkle (Very light Blue) #C5D7E7 RGB: (197,215,231) HSV: (208°, 14%, 90%) Color: Spindle (Very light Blue) #B5C6DC RGB: (181,198,220) HSV: (213°, 17%, 86%) Color: Spindle (Very light Blue) #BBC9DE RGB: (187,201,222) HSV: (216°, 15%, 87%) Color: Blue Haze (Light faded Blue) #B3BCCB RGB: (179,188,203) HSV: (217°, 11%, 79%) Color: Hawkes Blue (Very light Blue) #C9DEEF RGB: (201,222,239) HSV: (206°, 15%, 93%) Color: White (White) #F5FDFF RGB: (245,253,255) HSV: (192°, 3%, 100%)	HSV: (20°, 21%, 79%) Color: Malta (Faded Brown: Orange) #AC9187 RGB: (172,145,135) HSV: (16°, 21%, 67%) Color: Squirrel (Grey → Brown: Orange) #94776D RGB: (148,119,109) HSV: (15°, 26%, 58%) Color: Roman Coffee (Faded Brown: Orange) #7D5D52 RGB: (125,93,82) HSV: (15°, 34%, 49%) Color: Desert Sand (Very light Orange) #EECAAA RGB: (238,202,170) HSV: (28°, 28%, 93%) Color: Pancho (Light Orange) #E7B98E RGB: (231,185,142) HSV: (28°, 38%, 90%) Color: Sazerac (White → Orange) #F3DCCB RGB: (243,220,203) HSV: (25°, 16%, 95%) Color: Pot Pourri (White → Orange) #F5E1CF RGB: (245,225,207) HSV: (28°, 15%, 96%) Color: White (White) #F5FDFF RGB: (245,253,255) HSV: (192°, 3%, 100%)
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HSV: (272°, 61%, 16%) Color: Bali Hai (Blue) #7C94AD RGB: (124,148,173) HSV: (210°, 28%, 67%) Color: Regent St Blue (Cyan:Blue) #8FC2D5 RGB: (143,194,213) HSV: (196°, 32%, 83%) Color: Echo Blue (Light Blue) #9DB9D7 RGB: (157,185,215) HSV: (211°, 26%, 84%) Color: Rock Blue (Blue) #8E9FBB RGB: (142,159,187) HSV: (217°, 24%, 73%)	Color: Grey 90% (White) #DEDBE3 RGB: (222,219,227) HSV: (262°, 3%, 89%) Color: Logan (Grey → Blue) #9AA5B2 RGB: (154,165,178) HSV: (212°, 13%, 69%)
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Potassium color codes

Sufficient Potassium	Inadequate Potassium
Color: Alabaster k present2 (White → Orange: Yellow) #F0EEE8 RGB: (240,238,232) HSV: (45°, 3%, 94%) Color: Twilight Blue (White → Yellow) #F6F4E9 RGB: (246,244,233) HSV: (50°, 5%, 96%) Color: Forget Me Not (White → orange: Yellow) #FFF2DF RGB: (255,242,223) HSV: (35°, 12%, 100%)	Color: White (White) #FFFFFF RGB: (255,255,255) HSV: (0°, 0%, 100%) Color: White (White) #FFFFE1 RGB: (255,255,225) HSV: (60°, 11%, 100%) Color: Pumpkin (Orange) #FD8126 RGB: (253,129,38) HSV: (25°, 84%, 99%) Color: Navajo White (Very light Orange) #FEDCB1

Color: Maize (Orange: Yellow) #E2B87A RGB: (226,184,122) HSV: (35°, 46%, 88%) Color: Equator (Orange: Yellow) #D8AC66 RGB: (216,172,102) HSV: (36°, 52%, 84%) Color: Chenin (Orange: Yellow) #E3BE6F RGB: (227,190,111) HSV: (40°, 51%, 89%) Color: Corn Silk (White → Orange: Yellow) #FFF6DB RGB: (255,246,219) HSV: (45°, 14%, 100%) Color: Cape Honey (Very light Orange: Yellow) #FFE7A6 RGB: (255,231,166) HSV: (43°, 34%, 100%) Color: Varden (White → Orange: Yellow) #FFF2D2 RGB: (255,242,210) HSV: (42°, 17%, 100%) Color: Blanched Almond (White → Orange: Yellow) #FFF1CB RGB: (255,241,203) HSV: (43°, 20%, 100%) Color: Banana Mania (Very light Orange: Yellow) #FFE8AC RGB: (255,232,172) HSV: (43°, 32%, 100%) Color: Oasis (White → Orange: Yellow) #FFEFC5 RGB: (255,239,197)	RGB: (254,220,177) HSV: (33°, 30%, 99%) Color: Swiss Coffee (Very light Brown: Orange) #DDCF9 RGB: (221,207,201) HSV: (18°, 9%, 86%) Color: Spring Wood (White → Orange) #E9DFD5 RGB: (233,223,213) HSV: (30°, 8%, 91%) Color: Alto (Light Grey → Violet: Pink) #D0C2C8 RGB: (208,194,200) HSV: (334°, 6%, 81%) Color: Alto (Light Grey → Violet) #C9C3CB RGB: (201,195,203) HSV: (285°, 3%, 79%) Color: Careys Pink (Brown: Red) #BF9F99 RGB: (191,159,153) HSV: (9°, 19%, 74%) Color: White (White) #FFF9E7 RGB: (255,249,231) HSV: (45°, 9%, 100%) Color: Grey 90% (White) #FEF3E2 RGB: (254,243,226) HSV: (36°, 11%, 99%) Color: Grey 90% (White) #FCEFE5 RGB: (252,239,229) HSV: (26°, 9%, 98%) Color: White (White) #FDFCF9
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HSV: (43°, 22%, 100%) Color: Shalimar (Very light Yellow) #FFF3AC RGB: (255,243,172) HSV: (51°, 32%, 100%) Color: Corn Field (White → Yellow) #FFFBBF RGB: (255,251,191) HSV: (56°, 25%, 100%) Color: Light Yellow (White → Yellow) #FFFBE0 RGB: (255,251,224) HSV: (52°, 12%, 100%) Color: Lemon Chiffon (White → Yellow) #FFF9C7 RGB: (255,249,199) HSV: (53°, 21%, 100%) Color: Barley White (Very light Orange:Yellow) #F7E9BC RGB: (247,233,188) HSV: (45°, 23%, 96%) Color: Alabaster (White → Yellow) #F0EFE8 RGB: (240,239,232) HSV: (52°, 3%, 94%) Color: Butter (Yellow) #FFE946 RGB: (255,233,70) HSV: (52°, 72%, 100%) Color: Dandelion (Orange: Yellow) #FFD460 RGB: (255,212,96) HSV: (43°, 62%, 100%) Color: Tangerine Yellow (Yellow: Orange) #FFCF08 RGB: (255,207,8)	RGB: (253,252,249) HSV: (45°, 1%, 99%) Color: White (White) #FFFDFB RGB: (255,253,251) HSV: (30°, 1%, 100%)
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HSV: (48°, 96%, 100%)

Color: Salomie (Light Orange: Yellow)

#FFDE7F

RGB: (255,222,127)

HSV: (44°, 50%, 100%)

Color: Neon Carrot (Orange)

#FD8B2F

RGB: (253,139,47)

HSV: (26°, 81%, 99%)

Color: Sweet Corn (Light Yellow: Orange)

#FFE169

RGB: (255,225,105)

HSV: (48°, 58%, 100%)

Color: Bisque (White → Orange: Yellow)

#FFE5C2

RGB: (255,229,194)

HSV: (34°, 23%, 100%)

Color: Dark Tangerine (Orange: Yellow)

#FF9D11

RGB: (255,157,17)

HSV: (35°, 93%, 100%)

Color: Witch Haze (Light Yellow)

#FFED7B

RGB: (255,237,123)

HSV: (51°, 51%, 100%)

Color: Lemon Chiffon (White → Yellow: Green)

#FFFFC7

RGB: (255,255,199)

HSV: (60°, 21%, 100%)

Color: Cream (White → Yellow: Green)

#FFFFCF

RGB: (255,255,207)

HSV: (60°, 18%, 100%)

Color: Golden Glow (Light Orange: Yellow)

#FEDB85

RGB: (254,219,133)

HSV: (42°, 47%, 99%) Color: Salomie (Light Orange: Yellow) #FFDA7E RGB: (255,218,126) HSV: (42°, 50%, 100%) Color: Dandelion (Orange: Yellow) #FFD85E RGB: (255,216,94) HSV: (45°, 63%, 100%) Color: Kournikova (Orange: Yellow) #FFD351 RGB: (255,211,81) HSV: (44°, 68%, 100%) Color: Desert Sand (Very light Orange) #E4CCAD RGB: (228,204,173) HSV: (33°, 24%, 89%)	
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PH Color code

Acidic <5	Neutral >6
Color: Cashmere (Light Brown: Orange) #D3AF9B RGB: (211,175,155) HSV: (21°, 26%, 82%) Color: Rose (Brown: Orange) #CEA793 RGB: (206,167,147) HSV: (20°, 28%, 80%) Color: Spanish White (Very light Orange: Yellow) #E4D1B6 RGB: (228,209,182) HSV: (35°, 20%, 89%) Color: Lemon Chiffon (White → Yellow) #FEF9C7 RGB: (254,249,199)	Color: Titan White (Light faded Violet) #DCD2E2 RGB: (220,210,226) HSV: (277°, 7%, 88%) Color: Mercury (Light Grey → Violet: Pink) #D8CCD7 RGB: (216,204,215) HSV: (305°, 5%, 84%) Color: Prim (Light Grey → Violet: Pink) #DCCFD9 RGB: (220,207,217) HSV: (313°, 5%, 86%) Color: Prim (Light faded Violet: Pink) #DCCCD3 RGB: (220,204,211) HSV: (333°, 7%, 86%)

HSV: (54°, 21%, 99%) Color: Bison Hide (Faded Brown: Orange) #B7A59A RGB: (183,165,154) HSV: (22°, 15%, 71%) Color: Linen neutral (White → Orange: Yellow) #F7F1E4 RGB: (247,241,228) HSV: (41°, 7%, 96%) Color: Papaya Whip (White → Orange: Yellow) #FDEDD6 RGB: (253,237,214) HSV: (35°, 15%, 99%) Color: Sauvignon (White → Orange) #F6E9E2 RGB: (246,233,226) HSV: (21°, 8%, 96%) Color: Peach-Orange acidic (Very light Orange) #FBCB97 RGB: (251,203,151) HSV: (31°, 39%, 98%) Color: Peach-Orange (Very light Orange) #FDD09D RGB: (253,208,157) HSV: (31°, 37%, 99%) Color: Frangipani (Very light Orange) #FED39F RGB: (254,211,159) HSV: (32°, 37%, 99%) Color: Pink Lady (Very light Orange) #F8D6B4 RGB: (248,214,180) HSV: (30°, 27%, 97%) Color: Peach-Orange (Very light Orange)	Color: Amour (White → Violet: Pink) #F1E7ED RGB: (241,231,237) HSV: (324°, 4%, 94%) Color: Pale Cornflower Blue (Very light Blue) #B6D5F4 RGB: (182,213,244) HSV: (210°, 25%, 95%) Color: Light Cyan (White → Cyan:Blue) #DEF3FC RGB: (222,243,252) HSV: (198°, 11%, 98%) Color: Ebb (White → Red: Orange) #E8D6D4 RGB: (232,214,212) HSV: (6°, 8%, 90%) Color: Soft Peach (White → Red) #ECDEDF RGB: (236,222,223) HSV: (355°, 5%, 92%) Color: Whisper (White → Orange) #EFE7E3 RGB: (239,231,227) HSV: (20°, 5%, 93%) Color: Pumice (Light Grey → Green) #BEC8B5 RGB: (190,200,181) HSV: (91°, 9%, 78%) Color: Jet Stream (Light Grey → Green) #BFD0C8 RGB: (191,208,200) HSV: (151°, 8%, 81%) Color: Pumice (Light Grey → Green) #BDC6B7 RGB: (189,198,183) HSV: (96°, 7%, 77%)
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#F9CE99 RGB: (249,206,153) HSV: (33°, 38%, 97%) Color: Oasis (White → Yellow: Orange) #FFF2C7 RGB: (255,242,199) HSV: (46°, 21%, 100%) Color: Banana Mania (Very light Yellow: Orange) #FFF2B7 RGB: (255,242,183) HSV: (49°, 28%, 100%) Color: Lemon Chiffon (White → Orange: Yellow) #FFF3CD RGB: (255,243,205) HSV: (45°, 19%, 100%) Color: Varden (White → Orange: Yellow) #FFF1CE RGB: (255,241,206) HSV: (42°, 19%, 100%) Color: Spring Wood (White → Orange: Yellow) #E9E3DA RGB: (233,227,218) HSV: (36°, 6%, 91%) Color: Tuft Bush (Very light Orange) #FBD3BB RGB: (251,211,187) HSV: (22°, 25%, 98%) Color: Tuft Bush (Very light Orange) #FBD2B9 RGB: (251,210,185) HSV: (22°, 26%, 98%) Color: Varden (White → Orange: Yellow) #FDEDD0 RGB: (253,237,208) HSV: (38°, 17%, 99%)	Color: Granny Apple (Very light Green) #CADFCB RGB: (202,223,203) HSV: (122°, 9%, 87%) Color: Iceberg (Very light Green:Cyan) #C3DBD7 RGB: (195,219,215) HSV: (170°, 10%, 85%) Color: Opal (Light Green) #A7CBBF RGB: (167,203,191) HSV: (160°, 17%, 79%) Color: Gum Leaf (Light Green) #A3C5B2 RGB: (163,197,178) HSV: (146°, 17%, 77%) Color: Pixie Green (Light faded Green) #B4C7A7 RGB: (180,199,167) HSV: (95°, 16%, 78%) Color: Edgewater (Very light Green) #C0D8CE RGB: (192,216,206) HSV: (155°, 11%, 84%) Color: Jet Stream (Very light Green) #BBD4C8 RGB: (187,212,200) HSV: (151°, 11%, 83%) Color: Vista Blue Neutral (Light Green) #9FCCB4 RGB: (159,204,180) HSV: (148°, 22%, 80%) Color: Surf (Light Green) #B5D7C3 RGB: (181,215,195) HSV: (144°, 15%, 84%) Color: Grey 90% (White)
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Color: Chamois (Light Orange: Yellow) #EDD196 RGB: (237,209,150) HSV: (40°, 36%, 92%) Color: Marzipan (Light Orange: Yellow) #EDCE83 RGB: (237,206,131) HSV: (42°, 44%, 92%)	#F2ECEF RGB: (242,236,239) HSV: (330°, 2%, 94%) Color: Soft Peach (White → Pink: Red) #E9DBDE RGB: (233,219,222) HSV: (347°, 6%, 91%) Color: Spring Wood (White → Red) #EADCDB RGB: (234,220,219) HSV: (4°, 6%, 91%) Color: Lola (Light Grey → Blue: Violet) #B2AFBE RGB: (178,175,190) HSV: (251°, 7%, 74%) Color: Blue Haze (Light faded Blue) #B9BDCD RGB: (185,189,205) HSV: (228°, 9%, 80%) Color: Light Steel Blue (Very light Blue) #B3C5DE RGB: (179,197,222) HSV: (214°, 19%, 87%) Color: Link Water (Very light Blue) #C2CBDC RGB: (194,203,220) HSV: (219°, 11%, 86%)
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9. Makerere soil Testing Kit guide

Procedure:

1. Transfer a spatulaful of soil to the test tube.
2. Add 24 drops (or 1 ml) of solution K1 and shake vigorously for about 1 minute.
3. Add three (3) drops of K2 and shake gently.
4. Let stand for 5 minutes or until a clear orange solution on top of the soil.
5. Add solution K3 by:
 - a. Slowly inserting the dropper containing 0.5 ml of solution K3 inside the test tube so that its tip is about 1 cm above the solution.
 - b. Slowly add 0.5 ml one drop at a time.

DO NOT MIX OR SHAKE THE SOLUTION.

6. Let it stand for two minutes. Then observe the appearance of a cloudy yellow layer on top of the orange solution. Presence of a distinct cloudy yellowish layer indicates that the soil has sufficient available potassium.
7. If no yellowish cloudy layer appears on top of the orange solution, the soil is deficient in available potassium.

ORGANIC MATTER

Please note that the reagent is very corrosive so take a lot of care while handling it.

Principle

A vigorous reaction when reagent OM is applied directly to the soil sample indicates high organic matter (OM). A faint reaction shows that the amount of OM is low.

Procedure

1. Fill a small container (could be cover of soda/beer bottles) with soil.
2. Add 4-5 drops of reagent OM.
3. Observe the reaction vigour and note the time of reaction.
4. Conclude as low (0-5 sec.), high (5-10 sec), very high (> 10 sec)

(4)



DEPARTMENT OF SOIL SCIENCE
MAKERERE UNIVERSITY

SOIL FIELD TEST KIT

P. O. BOX 7062, KAMPALA
TEL: 041 540707

E-mail: soilscience@agric.mak.ac.ug

INSTRUCTIONS ON HOW TO USE THE KIT

Importance

The Soil Test Kit (STK) has been developed to assist farmers diagnose their soils to address the fertility requirements for crop growth. The kit is inexpensive, quick, handy and easy to use. It contains chemical reagents for the on-the-spot determination of pH, Organic matter, Nitrogen, Phosphorous and Potassium.

The results are interpreted and used as a basis for making a recommendation on the right kind and amount of fertilizer to be applied for a particular crop (see attached details).

SOIL pH TEST

Principle

A calibrated quantity of soil is shaken with a measured volume of indicator dye under consistent conditions and the pH of the color produced is then matched with a standard color chart.

(1)

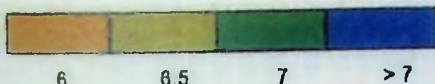
Procedure:

1. Transfer 1 spoonful (provided) of soil sample into the small test tubes.
2. Add 1 ml or 2 ml for wet or dry soil respectively of distilled water and shake vigorously for 1 min.
3. Add 12 (0.5 ml) drops of D1 indicator dye.
4. Mix by gently swirling the test tube 20 times.
5. Let stand for at least 5 min and match the color of solution on top of the soil with the corresponding color chart of pH indicator dye D1.
6. If soil pH is equal to or greater than 6, repeat steps 1 to 5 using indicator D2 instead of D1. However, if soil pH is less than or equal to 5, repeat steps 1 to 5 using D3 instead of D1. These steps will give a more precise pH value.
7. Wash the test tube with water and then rinse with distilled water.

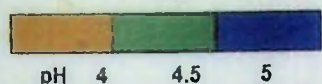
D1



D2



D3



NITROGEN TEST

Warning Reagents corrosive, handle with care and wear gloves

Principle

When solution N2 is added to a soil extract with solution N1, the following color changes may appear: deep blue, light or no color change at all.

Procedure:

1. Transfer 1 spoonful (provided) of soil sample into the big test tube.
2. Add 6ml of N1; then shake vigorously for about 1 min and let stand for 5 min.

(2)

3. Collect 2 drops of the clear supernatant into a small clean glass test tube.
4. With a separate dropper, add 12 drops of solution N2.
5. After 5 minutes, examine the test tube for any colour changes.
6. Deep blue colour indicates that N is adequate; light blue is inadequate and no colour change indicates lack of N.

PHOSPHORUS TEST

Principle

The blue color is produced on reduction of P reagent complex with the metal foil provided. This occurs when reasonable amount of phosphate ions are present in the solution. The intensity of the color is proportional to the amount of available phosphorus in the soil.

Procedure

1. Take a spoonful of soil sample into a clean test tube.
2. Add 48 drops (or 2 ml) of solution P and shake vigorously for about one minute.
3. Let the test tube stand for at least five (5) minutes.
4. Roll one of the metal foils provided in a polythene bag firmly on one end of the plastic rod.
5. Without disturbing the settled soil, slowly rub the metal between solution and test tube surface for 30 seconds.

Note: The metal attached to the rod can still be used for more tests but washed between them. If done on different days, then the metal should be re-cleaned.

6. The deep blue color indicates that P is high; light blue indicates adequate; green is for moderate while no colour change is for very low P.
7. Wash the test tube with tap water and then rinse with distilled water.

POTASSIUM TEST

Principle

The appearance of a distinct cloudy yellowish precipitate upper layer indicates sufficient available potassium and its absence on top of the clear orange solution, shows that the soil is deficient.

(3)

10. Introduction letter to the College of Agriculture and Environmental Sciences

MAKERERE UNIVERSITY
P.O. BOX 7072 KAMPALA UGANDA
URL: www.cis.mak.ac.ug
Tel: +256-43-786000
Fax: +256-43-786000

SCHOOL OF COMPUTING & INFORMATICS TECHNOLOGY
DEPARTMENT OF INFORMATION SYSTEMS

December 2019

The Head of Department Agricultural Production
College of Agriculture and Environmental Sciences
Makerere University

Thru The Soil Science Laboratory In charge
College of Agriculture and Environmental Sciences
Makerere University

Dear Sir Madam,

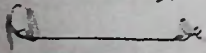
*Please Head
advise on the way
forward*

RE: LETTER OF INTRODUCTION FOR MR. MUTYABA ROBERT (2016/HD05/428U)

This letters serves to introduce to you Mr. Robert Mutyaba who is a final year MSc. in Information Systems student (Registration number: 2016/HD05/428U and Student number: 216018805) in the Department of Information Systems, School of Computing and Informatics Technology, at the College of Computing and Information Sciences (CoCIS) Makerere University.

Mr. Robert Mutyaba is currently conducting his final year research project where he aims to develop a mobile application for guiding analysis and recommendation of fertilizer application rates. It is expected that his solution can support decision making for farmers after carrying out soil nutrient tests.

Mr. Robert Mutyaba's research requires access to the soil science laboratory to consult and to perform experimental soil tests; this is needed to inform and guide the development of the use case for his mobile application. I hereby request you to grant permission to access these necessary resources in your college. I will greatly appreciate your positive consideration and approval.

Yours faithfully,


Dr. Peter Nabende,
Supervisor, Lecturer & Acting Chair, Department of Information Systems, SCIT, CoCIS, Mak

11. Soil samples Results (part)

Sample no.	Coordinates (Decimal Degree)		Sample depth (cm)	Soil Chemical Properties				Soil physical properties				Land use
	Latitude (Degree South)	Longitude (Degree East)		pH	N(%)	P(1b/a)	K(%)	Soil moisture(%)	Soil class	Colour Code	Colour	
1	0.30429	31.66714	0-30	7.0	10	75		62.7	Gleysol	5Y 3/1	Very dark gray	Fish pond
2	0.30417	31.66738	0-30	8.0	10	25		27.6	Gleysol	5Y 4/1	dark grey	Fish pond
3	0.30390	31.66717	0-30	7.0	60	75		31	Gleysol	5Y 4/1	dark grey	Fish pond
4	0.30352	31.66706	0-30	4.0	10	75		50	Gleysol	5Y 3/1	Very dark gray	Fish pond
5	0.30407	31.66664	0-30	8.0	150	80		27.7	Gleysol	10YR 3/2	Verydark grayish	Fish pond
6	0.30370	31.66440	0-30	6.0	20	150		15.2	Rhodic Ferralsol	5YR 3/2	Dark redish brwon	Coffee Plantation
7	0.30432	31.66432	0-30	6.0	40	75		18.9	Rhodic Ferralsol	5YR 3/2	Dark redish brwon	Coffee Plantation
8	0.30464	31.66418	0-30	6.0	40	25		18.6	Rhodic Ferralsol	5YR 3/3	Dark redish brwon	Coffee Plantation
9	0.30482	31.66415	0-30	7.0	20	150		23.5	Rhodic Ferralsol	5YR 3/2	Dark redish brwon	Coffee Plantation
10	0.30482	31.66434	0-30	6.0	20	150		13.3	Rhodic Ferralsol	5YR 3/3	Dark redish brwon	Coffee Plantation
11	0.30467	31.66360	0-30	6.5	60	75		17.7	Rhodic Ferralsol	5YR 2.5/2	Dark redish brwon	Banana Plantation
12	0.30474	31.66310	0-30	7.0	100	150		27	Rhodic Ferralsol	5YR 3/2	Dark redish brwon	Banana Plant

												ion
13	0.30467	31.6627 5	0-30	6. 0	60	150		32.7	Rhodic Ferrals ol	5YR 3/3	Dark redish brwon	Bana na Plant ion
14	0.30444	31.6626 5	0-30	5. 5	10 0	150		27	Rhodic Ferrals ol	5YR 2.5/2	Dark redish brwon	Bana na Plant ion
15	0.30391	31.6627 6	0-30	6. 0	10 0	150		20	Rhodic Ferrals ol	5YR 2.5/2	Dark redish brwon	Bana na Plant ion
16	0.03040	31.6602 0	0-30	8. 0	40	100		14.2	Plinthic Ferrals ol	5YR 2.5/3	Dark redish brwon	Pastu re land
17	0.30299	31.6600 4	0-30	8. 0	10 0	100		25.5	Plinthic Ferrals ol	5YR 3/2	Dark redish brwon	Pastu re land
18	0.30190	31.6600 1	0-30	8. 0	20	75		15.6	Plinthic Ferrals ol	5YR 3/2	Dark redish brwon	Pastu re land
19	0.30360	31.6659 9	0-30	8. 0	60	75		17	Plinthic Ferrals ol	5YR 3/2	Dark redish brwon	Pastu re land
20	0.30333	31.6596 6	0-30	6. 4	20	100		6.7	Plinthic Ferrals ol	5YR 2.5/2	Dark redish brwon	Pastu re land
21	0.30280	31.6589 8	0-30	6. 0	10	150		12.8	Plinthic Ferrals ol	5YR 2.5/2	Dark redish brwon	Pastu re land
22	0.30276	31.6584 2	0-30	6. 0	15	80		15.7	Plinthic Ferrals ol	5YR 2.5/3	Dark redish brwon	Pastu re land
23	0.30251	31.6578 0	0-30	7. 0	20	75		19.6	Plinthic Ferrals ol	5YR 3/3	Dark redish brwon	Pastu re land
24	0.30198	31.6581 9	0-30	7. 0	10	80		20.6	Plinthic Ferrals ol	5YR 2.5/1	Dark redish brwon	Pastu re land

12. Pictorial evidence



Soil samples that were collected and used



Purple suspension

Picture showing some of the soil PH results

Brown suspension



Picture showing Potassium results obtained during the process of system development



The Researcher identifying soil nutrient level using the Bujjimu APP