

**EXAMINING UGUNDUZI APP IN ENHANCING SMALLHOLDER FARMERS
ON FARMER-LED RESEARCH OF AGRO-ECOLOGICAL PRACTICES IN
TANZANIA**

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**A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR
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EXTENDED ABSTRACT

Background: Smallholder farmers play a key role in feeding world population. In recent decades a challenge of shrinking crop productivity was observed to face many smallholder farmers, particularly in African countries. Food deficit was among significant consequences reported to affect this group. Climate change, caused by environmental pollution, is a major contributor to low food productivity performance. Transforming food production system to protect environment for climate change resilience is regarded as a better way for increasing crop productivity to meet food demand. Agro-ecological practices could suit this platform as they use natural resources in production system. Farmer-led research of agro-ecological practices (FLRAG) is considered as a key supporter to farmers on identifying best-fit among many agro-ecological practices available in their areas. In the same vein of supporting farmers, smallholder farmers in particular, SWISSAID Tanzania developed a smartphone based app named *Ugunduzi* aiming to uphold farmers in their research activities. The app was intended to enhance farmers on field data collection, record keeping, share information and calculate costs used and benefits obtained on a per plot basis. It was developed in 2018 with participation of farmers and ICT experts. The app started being used by a small group of 60 smallholder farmers since 2019. However, its potential in supporting farmers in FLRAG has not been documented. This study aimed to examine the *ugunduzi* app for validating its potential to smallholder farmers on FLRAG in Tanzania.

Research methodology: The study was conducted in Bagamoyo, Masasi and Mvomero Districts, Tanzania. Before selecting participants in FLRAG and use of the *ugunduzi*, a baseline survey was conducted to identify factors influencing smallholder farmers to participate in the research. The aim was to set the criteria for selecting responsible

participants in FLRAG by considering identified factors. Ninety smallholder farmers were interviewed using a structured questionnaire to collect quantitative data during baseline survey. Binary logit model in SPSS programme version 26 was used to analyse the data to identify factors influencing farmers to participate in FLRAG. Qualitative data were also collected and analysed using content analysis to explain what was observed with quantitative data. Thereafter, the criteria for selecting participants were formulated by considering identified factors. Smallholder farmers who met the criteria were identified from the study areas, and then 60 farmers were selected to participate in FLRAG and use the *Ugunduzi* app. Time series research method was used in the study. The research was conducted in three seasons of 2019, 2020 and 2021. In examining the *Ugunduzi* app, the study specifically intended to examine continuance intention of using the *Ugunduzi* app among Tanzanian smallholder farmers. This was done by examining farmers' perception of usefulness and easiness of use which could lead to user satisfaction of the app and predict continuance intention of use. Identification of challenges on using the app and its limitation were also an aim of this study. Because farmers participated in FLRAG, investigation on the effects of agro-ecological practices in crop yield from the research was also an objective of the study. Field data were drawn from the *Ugunduzi* app in which participants used to collect and keep data. The data were also collected during field visits by using a structured questionnaire. Observation technique and focus group discussions were also conducted to collect qualitative data. Descriptive statistics were computed as part of quantitative data analysis to measure means and percentages. Partial least square structural equation modelling (PLS-SEM) using smartpls 3 was used to examine continuance intentions of using the *Ugunduzi* app. Excel software was used to measure average yields from agro-ecological treatments and control plots. R-software was used to determine the effects of the agro-ecological practices on crop yield from FLRAG.

Findings and conclusions: From the research, it was identified that experience in farming, easiness in accessing agro-ecological inputs, interest in doing experiments and farm size were the factors that substantially influenced smallholder farmers to participate in FLRAG. On examining the *Ugunduzi* app, the results indicated that the app satisfied smallholder farmers and showed possibility of continuous usage by them. This was due to its usefulness on supporting them to identify best-fit agro-ecological practices and to have better future season plan through records kept in the app. The app also showed greater potential on increasing agro-ecological knowledge through sharing information to the *ugunduzi* web-site via the *Ugunduzi* app. However, difficulties on using the app among smallholder farmers were observed, especially at the early stage of using it due to some processes involved. The issues of low practical experience of using smartphones, poor network connectivity, inadequate electrical power supply and limited purchasing power of smartphones were observed as the main challenges which many smallholder farmers faced in study areas. On the limitations side, it was identified that *Ugunduzi* app is a one-way communication app which runs on Android based smartphones supported by a Google Chrome web browser. The app was developed to support farmers who apply agro-ecological cropping practices only and is not suitable for illiterate farmers. On the effects of agro-ecological practices on crop yield from FLRAG, the results indicate that there were positive significant effects of the practices, particularly cow dung and poultry manure, on crop yield. From the findings, it is concluded that the *Ugunduzi* app positively supports smallholder farmers and is a valid tool to be promoted for using by many farmers in their agro-ecological areas and farming activities.

Recommendations: From the study findings, it is recommended that key stakeholders including service providers of network and electricity power suppliers should work on reducing challenges of low network and power cut-outs in the study areas and other parts

in Tanzania which face the same challenges. The government of Tanzania is advised to reduce costs of purchasing smartphone devices and promote their uses due to their usefulness, including using the *Ugunduzi* app. It is recommended that, the Ministry of Agriculture and NGOs dealing with agro-ecology to promote the use of the *Ugunduzi* app in FLRAG for quality research results of identifying best practices which could increase crop productivity. ICT experts should take *Ugunduzi* app limitations as a way forward on developing improved apps which are more suitable to smallholder farmers in Tanzania and Africa in general. Suggestion is also provided to the government of Tanzania, through its Ministry of Agriculture to (i) promote the uses of agro-ecological practices by many farmers, cow dung and poultry manure in particular as among of strategic approaches for increasing crop yield, (ii) Encourage more FLRAG for identifying more beneficial practices by smallholder farmers, and (iii) Encourage investment in agro-ecological practices particularly cow dung and poultry manure to mitigate the problem of inadequate availability of inputs. Furthermore, on selecting participants, identified factors have to be taken into consideration on setting criteria for selecting participants in FLRAG.

DECLARATION

I, Luambano Kihoma do hereby declare to the Senate of Sokoine University of Agriculture, Morogoro, Tanzania, that this thesis is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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DEDICATION

I dedicate this work to the Almighty God for his infinity blessings in my life. I also dedicate the work to my beloved mom Theresia Clement and my lovely son Michael Emmanuel Charles. Their constant love and prayers provided me strength for continuation.

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3. Challenges and limitations from using *ugunduzi* app in farmer-led research of agro-ecological practices among smallholder farmers in Tanzanian.
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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
AU	African Union
CSAG	Climate Smart Agriculture Guideline
ECA	Economic Commission for Africa
ECT	Expectation Confirmation Theory
FAO	Food and Agriculture Organization of the United Nations
FLRAG	Farmer-led Research of Agro-ecological Practices
IBM	International Business Machines Corporation
ICT	Information and Communication Technologies
ITU	International Telecommunication Union
MAFAP	Monitoring African Food and Agricultural Policies
MALF	Ministry of Agriculture Livestock and Fisheries
MUCHALI	Mfumo wa Uchambuzi wa Uhakika wa Chakula na Lishe
NCAT	Nepal Conservation Approaches and Technologies
PLS-SEM	Partial Least Square Structural Equation Modelling
PRA	Participatory Research Approach
SAT	Sustainable Agriculture Tanzania
SCLAA	Sociedad Científica Latino Americana de Agro-ecología
SPSS	Statistical Package of Social Sciences
TAM	Technology Acceptance Model
TOAM	Tanzania Organic Agriculture and Movement
TWN	Third World Network
URT	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

It is well known that smallholder farmers play a key role in feeding world population (Ricciardi, 2018). In African countries, among 75% of the population who are engaging in agricultural activities more than 90% are smallholder farmers (FAO and ECA, 2018). However, food insecurity is getting worse in this group (FAO and ECA, 2020). Despite many formal scientific researches having been done on improving smallholder farmers' crop productivity, most of the research results has had limited benefits (Fioret *et al.*, 2018). Farmer-led research could do better on this issue as it helps researchers and donors to study and understand the real needs of the farmers (Wettasinha *et al.*, 2014).

Farmer-led research is a type of participatory action research that empowers farmers to perform various research activities in close collaboration with a researcher (Fioret *et al.*, 2018). This type of research encourages farmers' innovation and capacity building to identify and co-develop suitable technological options to enable them cope with socio-economic and environmental conditions in their areas (Magunda *et al.*, 2010). In this research project, farmer-led research integrates agro-ecological practices with farmers' knowledge to innovate and improve farming in the production processes.

Agro-ecological practices are based on natural ecological processes applied to agricultural production systems. It links ecology, culture, economics and society to sustain agricultural productivity, healthy environments and viable food systems in the communities (Pimbert, 2011). For this study the emphasis was on agro-ecological cropping practices which include application of organic fertilizers, intercropping system, cover crops, mulching,

and application of biological pests and diseases control (Schoonhoven and Runhaar, 2018; Kwiatkowski and Harasim, 2020). Farmer-led research of agro-ecological practices are designed to involve all research activities from planning research to providing results in the farming communities (Fioret *et al.*, 2018).

In the development context, simple and useful methodologies tailored to smallholder farmers' needs are crucial to make smooth all research activities so as to maximize quality of research works. Within a Switzerland project based in Tanzania dealing with supporting local people who are suffering from hunger to get out of poverty (SWISSAID Tanzania), a mobile phone application software named *Ugunduzi* app was developed (SWISSAID Report, 2017). *Ugunduzi* is a Swahili word which means discovery or identification.

The aim of the app development was to support farmers to discover profitable agro-ecological technologies which could improve crop production with low costs. The app is based on smart phone technology which enables users to collect data of crops and agro-ecological treatments (pests and diseases control and soil management) of a "per-plot basis and keep records in the form of text messages, images and audio. Therefore, through data collected and kept in the app, farmers could understand costs used and benefits obtained per each plot.

In *Ugunduzi* app, data collection and keeping activities could be done when the user is offline but, to share them on the *Ugunduzi* website, the user must be connected to the internet. The data that could be shared in *Ugunduzi* website for others to see and learn from are those in the form of images and audio. The written data captured in *the app* can be analysed to understand the costs used and benefits obtained and remain the owner's

property and is secured as private records. It is a one way communication design app which comprises two language versions, English and Kiswahili. Users of the app can choose which language is more comfortable to use.

The *Ugunduzi* app is a new application which was introduced in 2018 within a co-design process of Information and Communication Technologies (ICT) experts with the participation of farmers who are engaged in adopting agro-ecological practices in their production processes. Smallholder farmers from three different districts of different regions in Tanzania were involved during its development. The districts are Bagamoyo, Masasi, and Mvomero from Coast, Mtwara and Morogoro Regions respectively in Tanzania. According to SWISSAID report (2017), the reason of selecting smallholder farmers from these districts to participate in the development of the *Ugunduzi app* was because they reflect and represent different agro-ecological zones in Tanzania. The zones are Coastal Region (Coast), Southern Region (Mtwara) and Central Region (Morogoro). On the other hand, the districts represent farming communities with differing degrees of exposure to agro-ecological trainings and support. Masasi farmer communities are the least trained and mostly in rural areas; they receive support since a couple of years through SWISSAID local office. The Bagamoyo farmers are used to collaborate with government extension support but have received little training in agro-ecological methods while the Mvomero farmers received training and support in agro-ecological farming practices through Sustainable Agriculture Tanzania (SAT) (SWISSAID Report, 2017).

The idea of developing the *Ugunduzi* app came after identifying that agro-ecological research requires farmers' participation at all research activity levels including developing research support tools. Therefore, the *Ugunduzi* app was developed purposefully to be used as a tool to support farmers who apply agro-ecological practices for data collection,

record keeping and analysis. The collected data can also be shared for others to learn. During its development, a series of workshops between the app developer and smallholder farmers were conducted. In the workshops, farmers proposed their ideas, which were tested and refined until the final version that reflected the needs of the farmers were produced (SWISSAID Tanzania 2017). The app started to be used by a small group of farmers in their farming activities since 2019.

1.2 Problem Statement and Justification of the Study

Following worldwide climate change crisis, food insecurity phenomena has been among significant consequences observed in most African countries (FAO and ECA, 2018). The most affected group of people by this scenario is smallholder farmers who depend on agriculture as the main source of their livelihood (World Bank, 2016). In Tanzania, food shortage has been also experienced in most parts of the country particularly in rural areas (MAFAP, 2013). Promoting agro-chemical uses to increase crop yield was among the government strategies laid out to overcome this problem. However, progress towards getting enough food to cover smallholder farmer communities is still very low (MALF, 2017). Several literature sources have remarked that agro-ecological approaches could be a problem solver to this scenario (Wilbois and Schmidt, 2019; Kwiatkowski and Harasim, 2020; Paracchini *et al.*, 2020; Tiftonell *at al.*, 2020). The approaches apply natural resource bases which are available in many areas. In Tanzania, the approaches have started to bring positive results to most smallholder farmers (TOAM, 2015; NEPCAT, 2017). This is because many farmers who have been trained and advised to apply agro-ecological practices have been proved to boost productivity in inexpensive ways and maintain sustainable soil fertility (GCCA, 2014; TOAM, 2015). However, how this knowledge could scientifically be embraced and shared with many users remains a challenge. Therefore, preferable techniques which can capture local ideas and discover

better ones among many to be disseminated widely using formal publication were the suggested (Tambo and Wunscher, 2017; Agula *et al.*, 2018; Chizallet *et al.*, 2018; Pagliarino *et al.*, 2020). Farmer-led researches of agro-ecological practices (FLRAG) were viewed to be fit in this arena as they integrate farmers' innovations in collaboration with researchers who will publish findings in the form of publications to reach many people.

To support this exercise with the aim of having quality research, SWISSAID Tanzania launched a smartphone based app named *Ugunduzi*. The app intends to support farmers who apply agro-ecological approaches on data collection, record keeping, information sharing, and data analysis by providing results of costs used and benefits obtained (SWISSAID report, 2017). It was assumed that by having quality records kept in the app, farmers would be able to understand which agro-ecological practices are doing well for increasing productivity and the costs incurred. Farmers could also increase their knowledge on agro-ecological practices by understanding challenges and benefits of various agro-ecological approaches through sharing information via *Ugunduzi* app. Having enough information of several agro-ecological practices could help farmers to pick best-fit according to their environment for increasing productivity to reduce food deficit.

However, since the *Ugunduzi* app was launched in 2018 and since it started being used by farmers from 2019 to date no research was carried out to examine to understand its performance in supporting farmers. Therefore, this study was conducted with the aim of examining the *Ugunduzi* app to understand its importance to farmers in supporting their research activities. The study focused on usefulness and easiness of use of the app to farmers which could lead to user satisfaction in using the app to predict the continuance

usage by farmers. Identification of challenges of using the app and its limitations was also conducted. The findings from this study will provide better understanding of the validity of the *Ugunduzi app* as a tool for supporting farmers on improving crop productivity through agro-ecological practices. Through identified challenges and limitations of the app from the results, other apps initiators could be able to make modification or developing more suitable apps which could cope with the environment. Policy makers will be influenced to create conducive policy environment to encourage more application development for improving farming activities, particularly agro-ecological approaches.

1.3 Objectives

1.3.1 Overall objective of the study

The overall objective of the study was to examine the *Ugunduzi* app for validating its potential to smallholder farmers in enhancing farmer-led research on agro-ecological practices in Tanzanian.

1.3.2 Specific objectives of this study

Specifically the study aimed to:

- i. Determine factors influencing smallholder farmers to participate in farmer-led research of agro-ecological practices and use of the *Ugunduzi* app,
- ii. Examine continued intention of using the *Ugunduzi* app in farmer-led research of agro-ecological practices among smallholder farmers in selected areas, Tanzania,
- iii. Determine the challenges that smallholder farmers could encounter while using the *Ugunduzi* app and its limitations, and
- iv. To investigate the effects of agro-ecological practices in crop yield from farmer-led research of agro-ecological practices.

1.4 Research Questions

- i. What are the factors that motivate smallholder farmers to participate in farmer-led research of agro-ecological practices?
- ii. Does the *Ugunduzi app* have any positive potential to smallholder farmers on their way to improve crop productivity through farmer-led research on agro-ecological practices if they continue using it?
- iii. What are the challenges that smallholder farmers may encounter when using the *Ugunduzi app*?
- iv. What are the limitations of using the *Ugunduzi app*?
- v. Is there any effect of agro-ecological practices applied by smallholder farmers in yield from farmer-led research?

1.5 Theoretical Framework

Several theories were reviewed to identify the best one to guide the study. The Technology Validation Theory by Zelkowitz and Wallace (1997) was found to be the most suitable one to guide this study. The theory predicts performance of the technology before applying it to a large scale and using it for a long-term purpose. This is by applying the technology at a small scale for a short term, monitoring its performance and establishing the extent to which the prediction of its working is correct (Zelkowitz and Wallace, 1997). This study examined usefulness and easiness of use of the *Ugunduzi app* among smallholder farmers who apply agro-ecological approaches in their farming activities. The results could lead to user satisfaction and predict continuation usage of the app. If farmers would be satisfied and predict its continuation usage, the app would be validated and promoted to be used at a large scale. Otherwise the app will be dismissed. The theory was also used by Gogus *et al.* (2012) in validating Education Technology Acceptance (ETA) across cultures.

1.6 Conceptual Framework

The conceptual frame work of this study was developed by considering study objectives and variables which were measured.

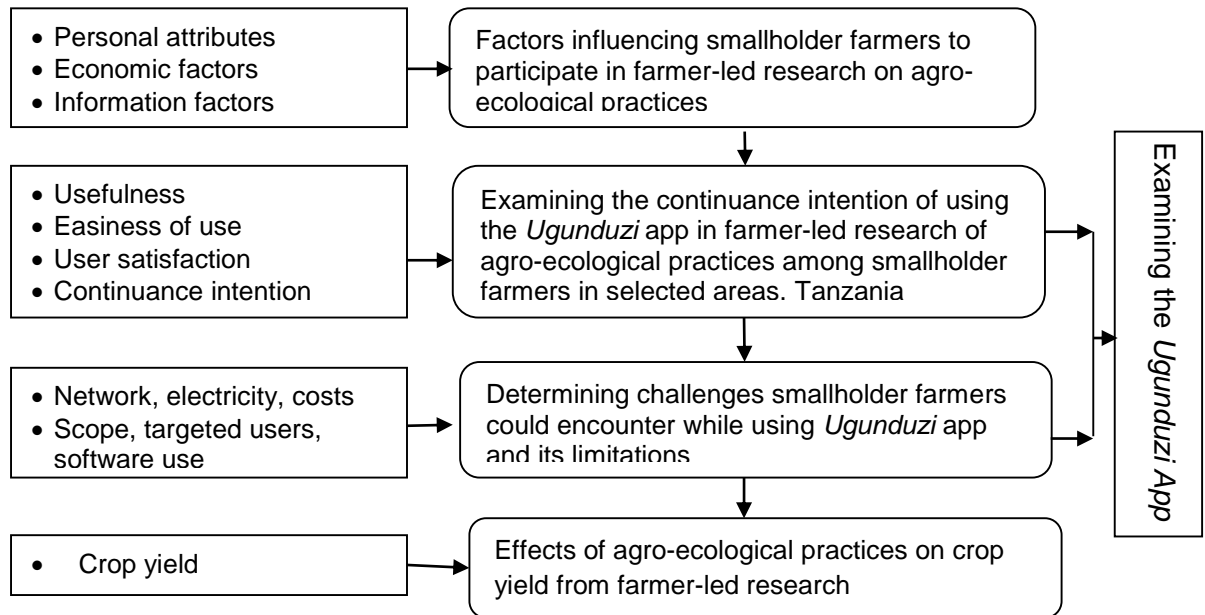


Figure 1.1: Conceptual frame work of the study modified from Churi (2013)

1.7 Study Limitations

The study focused on smallholder farmers who participated in FLRAG, specifically on only crop farming. The aim was to enable participants to use the *Ugunduzi* app for examining its validity to Tanzanian smallholder farmers. The *Ugunduzi* app was developed purposefully to support farmers who were applying agro-ecological cropping practices for data collection and record keeping, share information and calculate costs used and benefits obtained on per-plot bases.

- The first limitation occurred on the first objective of identifying factors influencing smallholder farmers to participate in FLRAG with the aim of selecting responsible respondents who would use the *Ugunduzi* app. Two groups of farmers one with farmers who participated and the other one with farmers who did not participated in FLRAG were involved in the study. A challenge arose on deciding the way to be used

to identify farmers who would participate in FLRAG within the selected area. To overcome this challenge, the study relied on selecting farmers who were members of farmer groups which were dealing with agro-ecological practices within particular areas.

- The second limitation arose on selecting participants to use the *Ugunduzi* app for examining its validity to Tanzanian smallholder farmers. Users of the *Ugunduzi* app had to follow processes available in the app by reading and writing. A challenge arose on selecting literate participants who at least knew how to read and write. To overcome this challenge, the study based on selecting participants who had at least completed standard seven of Tanzanian education.
- The third limitation of this study was on selecting agro-ecological practices applied by farmers to be investigated to understand yield levels. There were many agro-ecological practices applied by farmers within selected areas including cow dung manure, poultry manure, goat manure, compost, intercropping, mulching and application of biological pest and disease control measures. However, due to limited time available to accomplish this study of only 4 years, two practices were proposed to be selected for investigation. A challenge arose on how to select the practices. To overcome this challenge, the study relied on selecting practices which were mostly applied by farmers within the selected areas. During baseline survey it was revealed that cow dung and poultry manure had been being practised by many farmers within the selected areas. Therefore, the practices were chosen to be investigated to understand their effectiveness in increasing crop yield of this study.

1.8 Organization of Chapters

This thesis has five chapters. Chapter one is an introduction part which comprises background information, problem statement and justification of the study, objectives and research questions of the study. The chapter also covers theoretical and conceptual frameworks, limitations of the study and brief description of the organization of the study. Chapter two presents methods used in the study which include research design, research approach, the study areas, study population, sample size and sampling procedures of the study, data collection methods, data analysis and tables indicating analytical techniques used for each objective. Chapter three presents findings of the study which include papers published and manuscripts. Chapter four provides a brief discussion from the study findings. Chapter five summarizes conclusions and recommendations of the study.

CHAPTER TWO

2.0 RESEARCH METHODOLOGY

2.1 Research Design

Cross-sectional and time series research design was used in this study. Before selecting participants in FLRAG and using the *Ugunduzi*, a baseline survey was conducted to identify factors influencing smallholder farmers to participate in the research. The aim was to set some criteria on selecting responsible participants of FLRAG by considering identified factors. Cross-sectional research design was used during baseline survey. This design allows data to be collected at one point in one time to represent a large population (Babbie, 1990). Time series research design was used after selecting farmers to participate in FLRAG. The design allows data to be collected for the same subjects repeatedly over a period of time (Velicer & Fava, 2003). The data that were collected were analysed in three different seasons which are 2019, 2020 and 2021.

2.2 Research Approach

Participatory Research Approach (PRA) between the researcher and participants in FLRAG was used. Training on how to conduct quality research, procedures and rules of research was provided to participants at the early stage of the survey. Implementing, monitoring and observation techniques were used. Arrangement of activities in PRA is like a cycle; after finishing one activity, planning for another one starts as argued by (Gaffney, 2008), i.e. “Plan, act, observe, reflect”.

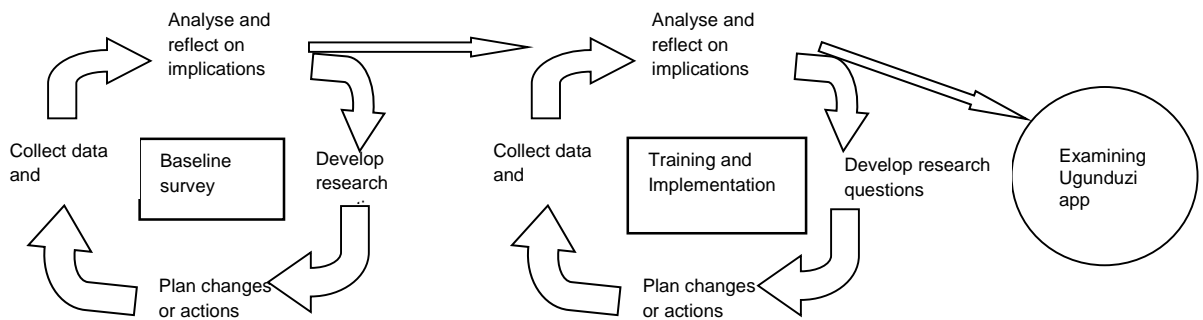


Figure 2.1: Participatory research cycle (Gaffney, 2008)

2.3 Description of the Study Area

The study was conducted in Bagamoyo, Masasi and Mvomero Districts of Coast, Mtwara, and Morogoro Regions respectively in Tanzania. The selection of the study areas was done based on socio-practical and socio-ecological reasons. Socio-practically, these study areas are those where farmers participated in the development of the *Ugunduzi app*. It was considered that it could be easier to work with farmers who were already familiar with the application of the *Ugunduzi app* and that they could relatively easily be motivated to participate due to their previous involvement in the development of the *app*. Socio-ecologically, these study areas had received training and practical exercises on agro-ecological practices from projects dealing with agro-ecology such as Chambezi Project Research Centre (CPRC) in Bagamoyo, Sustainable Agriculture Tanzania (SAT) in Mvomero and SWISSAID Tanzania in Masasi. It was assumed that local farmers around those areas would understand more about agro-ecological practices which is one of the key issues of the study.

2.4 Study Population, Sample size, and Sampling Procedure

2.4.1 Population

Smallholder farmers who were applying agro-ecological practices in production process were the study population. According to farmer group leaders of agro-ecological

practices, groups available in the study areas which were identified during a preliminary baseline survey had a total of 6 826 smallholder farmers who were applying agro-ecological practices. From the total, 2 850 smallholder farmers were in Mvomero District, 3 704 farmers lived in Masasi District and 272 farmers lived in Bagamoyo District

2.4.2 Sample size

During baseline survey, a total of 90 smallholder farmers were selected to take part in the study to determine factors influencing farmers to participate in FLRAG. After identifying factors influencing farmers to participate in the research, only 60 smallholder farmers who were applying agro-ecological practices in the farming production process were selected to participate in FLRAG. According to the formulae suggested by Anika (2021) on selecting sample size for a study, a total of 364 smallholder farmers were supposed to be selected during baseline survey and during farmer participation in FLRAG as indicated hereunder

Formulae

$$S = \frac{\frac{Z^2 \times P(1 - P)}{e^2}}{1 + \frac{Z^2 \times P(1 - P)}{e^2 N}}$$

Where

N = Population

Z = Z-Score

e = Margin of error

P = Standard of deviation

S = Sample size

In our case

$$N = 6\,826$$

$$Z = 1.96 \text{ at } 5\% \text{ level of confidence}$$

$$e = 0.05$$

$$P = 0.5$$

$$S = ?$$

Therefore:

$$S = \frac{\frac{(1.96)^2 \times 0.5 (1 - 0.5)}{(0.05)^2}}{1 + \frac{(1.96)^2 \times 0.5 (1 - 0.5)}{(0.05)^2 \times 6\,826}} = 364$$

However, due to limited resources including time and money for conducting this study, the researcher couldn't manage to have the proposed sample. According to Robin (1998), a minimum of 30 and above participants as sample size is enough to represent a large population for an experimental research which faces limited resources. By considering the limited resources already mentioned and that this was a kind of experimental research, 90 smallholder farmers were selected for conducting a baseline survey and 60 smallholder farmers were taken as the sample size to participate in FLRAG and provide data required for the study.

2.5.3 Sampling procedure

Multistage purposeful and simple random sampling techniques were used to select participants of this study. Firstly, civil society organizations which worked with farmers on promoting agro-ecological practices in Tanzania were identified through internet search, attending various workshops and reading newspapers. The organizations such as

SAT, Uluguru Mountains Agricultural Development Project (UMADEP), Tanzania Alliance for Biodiversity (TABIO), CPRC, Tanzania Organic Agriculture Movement (TOAM) and The SWISSAID Tanzania were identified. Secondly, visiting identified civil society organizations recognized from the mentioned ways was done. After the visits three organizations including CPRC, SWISSAID Tanzania and SAT from Bagamoyo, Masasi and Mvomero Districts respectively were selected. The selection of those organisations was based on two criteria. Firstly, the organizations had scientific research plots in which several agro-ecological approaches were carried out for investigation and providing training to farmers. Secondly, the organizations had farmers who were getting training on agro-ecological approaches and who had participated during the *Ugunduzi* app initiative. The assumption was to have participants who could have some ideas on agro-ecological approaches and *Ugunduzi* app.

After selection of the organizations within the above three districts, nearby wards to scientific research plots which had higher numbers of farmers who had participated in *Ugunduzi* app development were identified through a preliminary survey. Then one ward among those identified as expressed above was randomly selected in each district. The wards selected were Chambezi, Chigugu and Lubungo in Bagamoyo, Masasi and Mvomero districts respectively. Two villages in each selected ward were also randomly selected. The villages selected were Chambezi and Kongo from Chambezi Ward, Chigugu and Mbemba from Chigugu Ward and Lubungo and Menge from Lubungo Ward. During the baseline survey to determine factors influencing farmers to participate in FLRAG, a total of 90 smallholder farmers were randomly selected from the study areas, 15 from each village. After identifying factors from baseline survey, criteria for selecting participants in FLRAG were formulated. Smallholder farmers who met the criteria were identified from the study areas, then 10 smallholder farmers from each village were

randomly picked to have 60 who participated in FLRAG and use of the *Ugunduzi* app for examining its potential to farmers. The number of participants was equal in each village because the sample was small and we wanted to have experience from different areas.

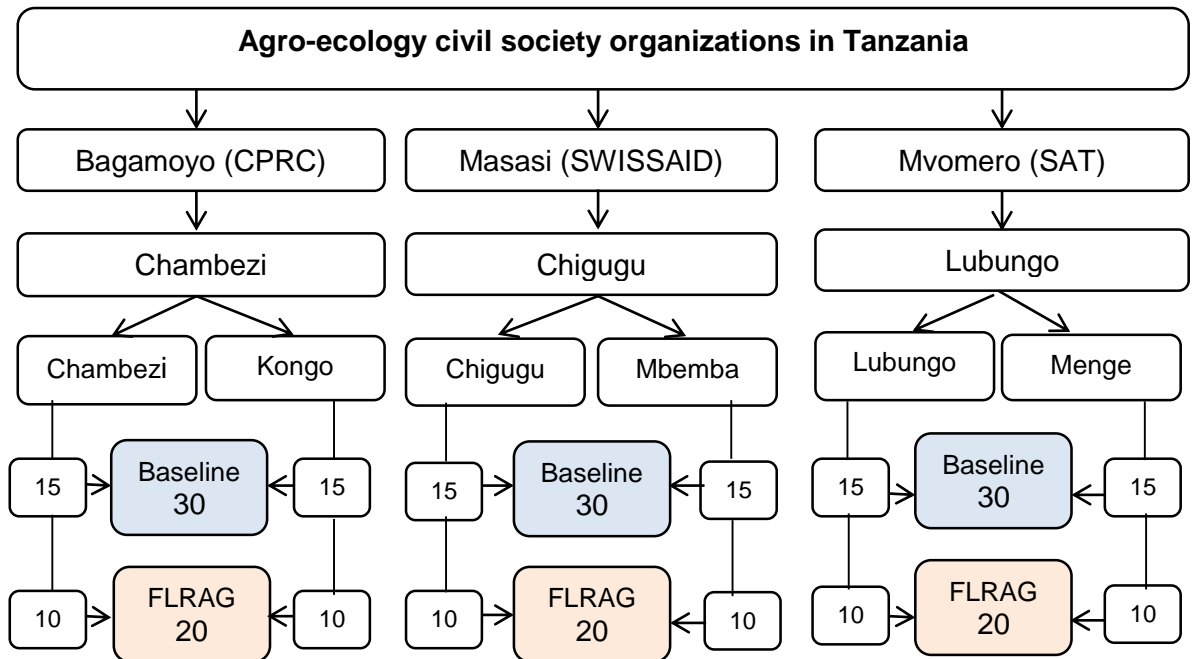


Figure 2.2: Schematic diagram of the sampling design for the study

2.6 Data Collection Methods

Quantitative and qualitative primary data were collected during baseline survey and in FLRAG survey. Secondary data were also collected for this study. A structured questionnaire was designed and used to collect quantitative data through individual interviews. The questionnaire was pre-tested, and modifications were made before conducting the research. Quantitative data were used for measuring quantifiable variables which were used in the study. Field data from research plots were drawn from the *Ugunduzi* app and during farm field visits. The *Ugunduzi* app is a smartphone based tool which participants use to collect and keep records of field data. Field data help to understand the potential of agro-ecological practices from FLRAG results. Qualitative data were collected through focus group discussions (FGD) with farmers, observation

technique, and from key informants. Designed guideline questions were used to collect data from FGD and from key informants. Key informants were the officers who selected from projects involved in this study and who had participated during the development of the *Ugunduzi* app. The projects included CPRC, SWISSAID and SAT. Observation technique was used to collect qualitative data during FLRAG. The technique helped to understand the reality from the ground through direct observation. The qualitative data supported findings by providing details of quantitative results. Secondary data were collected from different sources of information including libraries, internet, civil society organisations and government reports. The data were obtained by visiting relevant areas and searching the internet. The data helped understand what was there concerning agro-ecological practices and the *Ugunduzi* app.

2.7 Data Analysis

2.7.1 Qualitative data analysis

The qualitative data that were collected were analysed using content analysis in which transcripts from focus group discussions were coded to identify available themes for interpretations and discussion (Mariette, 2016; Erlingsson and Brysiewicz, 2017).

2.7.2 Quantitative data analysis

The quantitative data that were collected were analysed using the IBM Statistical Package of Social Sciences programme (SPSS) Version 26, Microsoft Excel software, smartpls software and R-software. For each specific objective, data were analysed as per the summary in Table 2.1.

Table 2.1: Summary of data collected and analytical techniques used per objective

No	Objectives	Data Collection	Analytical technique
1.	To determine factors influencing smallholder farmers to participate in farmer-led research of agro-ecological practices	1. Quantitative (Structured questionnaire) Qualitative (FGD)	1. SPSS-Binary logit model (quantitative) 2. Content analysis (qualitative)
2.	Examine continued intention of using the <i>Ugunduzi</i> app in farmer-led research of agro-ecological practices among smallholder farmers in selected areas, Tanzania	1. Quantitative (Structured questionnaire) 2. Qualitative (FGD) 3. Key Informant Interviews (KIIs)	1. PLS-SEM using smartpls (quantitative) 2. Content analysis (qualitative)
3.	Determine the challenges and their limitations while using the <i>Ugunduzi</i> app	1. Quantitative (Structured questionnaire) 2. Qualitative (FGD) (Observation)	1. Descriptive statistics 2. Content analysis (qualitative)
4.	To investigate the effects of agro-ecological practices in crop yield from farmer-led research	1. Quantitative (Structured questionnaire) (Field visits) 2. Qualitative (FGD)	1. One-way ANOVA using R-Software, Excel (quantitative) 2. Content analysis (qualitative)

CHAPTER THREE

3.0 PAPERS AND MANUSCRIPT

3.1 Paper one

Factors influencing smallholder farmers to participate in farmer-led research of agro-ecological practices in selected areas, Tanzania.

3.2 Paper two

Examining the continued intention of using the *Ugunduzi* app in farmer-led research of agro-ecological practices among smallholder farmers in selected areas, Tanzania.

3.3 Manuscript 1

Challenges and limitations of using *Ugunduzi* app in farmer-led research of agro-ecological practices among smallholder farmers in Tanzania

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3.3.1 Abstract

On the introduction of agricultural application, most developers consider environmental condition and social economic status of the users. Developers may end up setting some limitations on using the app to meet planned goals. On using the apps, some may meet challenges which could reduce effective uses and un-meet intended purposes. This study was carried out to identify challenges smallholder farmers could encounter while using the *Ugunduzi* app and limitations of using it. Qualitative data were collected from 60 smallholder farmers who participated in farmer-led research of agro-ecological practices and use of the *Ugunduzi* app in Bagamoyo, Masasi and Mvomero Districts in Tanzania.

Content analysis was used to analyse the collected data. The results indicated that lack of practical experience of using smartphones, poor network connectivity, inadequate electricity power supply and limited purchasing power of smartphones were the main challenges which faced many smallholder farmers in the study areas. On the limitations side, the study found that *Ugunduzi* app is a one way communication app which uses smartphone Android based on a Google Chrome web browser. The app was developed to support farmers who apply agro-ecological cropping practices only and is not suitable for illiterate farmers. From the results it is recommended that responsible stakeholders and service providers of network and electricity power supply to work on the observed challenges to reduce their adverse effects on using ICT apps particularly *Ugunduzi* app. App developers are urged to use the limitations identified to create apps which are more suitable to smallholder farmers in Tanzania and in Africa in general.

Keywords: *Ugunduzi* app, smallholder farmers, challenges and limitations

3.3.2 Introduction

Within the current world full of digital technologies, agricultural activities have not been neglected by development actors to initiate agricultural digital tools, to support sectorial development goals. Mobile devices including smartphones through various developed applications have been recognized as one of the key tools which changed agricultural stakeholders' ways of communicating, networking, sharing knowledge and performing several agricultural tasks (Crespo *et al.*, 2020; Maturano *et al.*, 2022). Efficient and effectiveness of the agricultural activities have been revealed on the appearance of smartphones agricultural apps (Sivakumar *et al.*, 2022). The great achievement on this was associated with the falling of purchasing price costs of the devices and regular declining costs of the services (Alliance for Affordable Internet, 2020). The situation led

to increasing penetration of smartphones apps uses into the agricultural sector with high fulfilment of users' needs (Pongnumkul *et al.*, 2015).

However, the circumstances differ among various smallholder farmers especially those in African countries. Despite a number of agricultural smartphone apps having indicated successful results, but many others in African countries have failed (Murugesan, 2013). The failure was often attributed to various challenges identified in many rural areas where smallholder farmers lived and work. The most common noted challenges are those associated with network failures, illiteracy among users, inability to charge phones due to inadequate electricity power supply, high cost perception on device purchasing, running costs among users, and unwillingness to cover costs for using agricultural apps among users (Capalbo *et al.*, 2017; Navinkumar *et al.*, 2018; Kenny and Regan 2021; Fox *et al.*, 2021). In addition, some apps introduced came with some limitations on using due to intended purposes of the app initiative, targeted group, environmental requirements and developers' interests (Tiselli *et al.*, 2016; Capalbo *et al.*, 2017; Dauma *et al.*, 2018; Navinkumar *et al.*, 2018; Crespo *et al.*, 2020).

Ugunduzi is one of the smartphone based app which was introduced purposefully to support farmers who apply agro-ecological practices (Kihoma *et al.*, 2023). Agro-ecological practices are farming approaches which consider ecosystem and utilization of natural resource based (Tittonell *et al.*, 2019). Several agricultural stakeholders have remarked that agro-ecological practices could be the right solution to smallholder farmers which could bring positive changes in the agricultural system within climate change environments (Mdee *et al.*, 2019; Milheiras *et al.*, 2022). Due to this, various actors have made concerted efforts to promote agro-ecological practices (Wezel *et al.*, 2020). As part of the efforts, SWISSAID Tanzania developed the *Ugunduzi* app aiming to support

farmers to identify best-fit agro-ecological practices through various research endeavours (SWISSAID report, 2017). For this study, the focus was on farmer-led research of agro-ecological practices (FLRAG). The idea was to encourage farmers to conduct research on agro-ecological practices to identify profitable ones and to disseminate findings widely through formal publications. Farmer-led research allows farmers to take a lead of investigation in collaboration with researchers who will assist processes of publishing findings to reach many people.

For this study, investigation was done to the *Ugunduzi* app which intended to support farmers who participated in FLRAG on data collection, record keeping, sharing information and calculating costs used and benefits obtained on a per plot basis. Despite the usefulness of the *Ugunduzi* app to smallholder farmers for supporting farmers' research activities as it was reported by Kihoma *et al.* (2023) in their study, the challenges smallholder farmers encountered in using the app and limitations on using it were not yet investigated. Therefore, the aim of this paper was to identify challenges and limitations of using the *Ugunduzi* app among smallholder farmers who participated in FLRAG. The results could be useful to stakeholders for finding out permanent solutions on the effective use of the *Ugunduzi* and other related apps. App developers may use the identified challenges and limitations to make some modifications in developing suitable technologies which will meet more demands of users within their environments to bring positive changes. Another aim of this paper was to contribute to literature related to uses of ICT apps in farmer-led research of agro-ecological practices.

3.3.3 Research methodology

A total of 60 smallholder farmers who were participating in FLRAG and using the *Ugunduzi* app during this survey were interviewed. The participants were selected from

Chambezi and Kongo Villages of Chambezi Ward in Bagamoyo District, Chigugu and Mbemba Villages of Chigugu Ward in Masasi District, and Lubungo and Menge Villages of Lubungo Ward in Mvomero District. The relatively big number of farmers who reported to engage in FLRAG and using the *Ugunduzi* app in these areas was the main reason of doing the research in those areas (Kihoma *et al.*, 2023). Enough experience of using the *Ugunduzi* app of not less than 2 years, age of not less 18 years, gender issues, and having completed at least standard seven of Tanzanian education were taken into consideration during selecting participants.

3.3.3.1 Data collection method

Quantitative and qualitative data were collected in this study. Six focus group discussions (FGDs), one in each village, were carried out. Each focus group comprised 10 members. A structured questionnaire was developed and used for a survey by considering the aim of the study. Probing questions to explore clarity of answers to the questions by various participants were used during the survey. Before starting each session, the participants were assured about privacy issues and that the information from them was only for the study purpose and not otherwise, and hence that they had to be free in expressing their views about the app. In all discussions, ethical matters including respecting each other during discussions, each participant had equal chances to contribute and was faithful to contribute to discussion topics which were introduced by the facilitator. The discussions took about 40 to 45 minutes in each group. An audio recording and a notebook for taking notes were used to collect data through discussions.



Figure 3.1: Among of the focus group discussion conducted at Chambezi village of Chambezi ward in Bagamoyo (left) and Mbemba Village of Chigugu ward in Masasi (right)

Data were also collected from key informants who were officers from the SWISSAID project in which the *Ugunduzi* app was developed with participation of farmers. The aim was to explore in detail about the *Ugunduzi* app initiative. Observation technique during the survey was also used to collect data for this study.

3.3.3.2 Data analysis

For qualitative data, transcription was done immediately after completion of a group discussion session to record ideas of the participants. Content analysis technique was used to analyse the transcripts. Content analysis is a research method which is used to determine the presence of certain concepts which have some messages within a given qualitative data set. In this study, conceptual content analysis was used. From the transcripts, data coding was done to identify reported concepts for examination. Thorough reading of the developed transcripts was done to enhance good organization of the identified concepts for broader themes and subthemes interpretation. Quantitative data were analysed using SPSS programme version 26 whereby frequencies and percentages of

demographic characteristics and challenges of using *Ugunduzi* app in farmer-led research of agro-ecological practices among smallholder farmers were computed.

3.3.4 Findings and Discussion

This study focus on exploring challenges Tanzanian smallholder farmers encountered from using the *Ugunduzi* app in FLRAG and app limitations from using. The overviews of the main themes are discussed through demographic characteristics of the respondents to understand challenges from using the app and perusing on the *Ugunduzi* app to investigate app limitations.

3.3.4.1 Demographic characteristics of the respondents

Out of 60 respondents who interviewed in this study, 51.7% were female and 48.3% were male. Based on age issues, most of them about 70% were above 36 years old. This may indicate that those in the young age group below 36 who engaged in farming activities were few of only 30%. For education, about 80% of the respondents interviewed from this study hold basic education. This could imply that the study areas dominated with low educated people (Table 3.1).

Finding from the study revealed that, most farmers within study areas had lack of practical experience of using smartphones. The *Ugunduzi* is a smartphone based app; users of the app should know how to use smartphones. This study identified that many smallholder farmers in all the study areas had little knowledge on using smartphones. During this survey, it was identified that only 20% of the participants owned smartphones before the *Ugunduzi* app initiative. Most farmers owned normal button mobile phones. Participants in this study reported that apart from high cost of purchasing smartphones, they didn't know the importance of having smartphones while they could communicate by

using simple, cheap and easy to use button mobile phones. The participants had perception that smartphones are for people who live in town centres and young people for using in social issues like WhatsApp, Facebook, twitter and instagram. “*Why I purchase a costly phone of more than 100 000/= (about 42.6 USD) while I can communicate with people using cheap phones of 20 000/= (about 8.5 USD)? Smartphones are for young generation and town people who like to peruse for luxury issues like whatsApp, Facebook, twitter and instagram*” (Eria Charles, in Menge village during personal communication with researcher). The participants continued to explain that those social matters for them as farmers were not important. They always sought to improve production for feeding their families and meeting other basic needs like shelters, cloths and communication. This situation led to undermine effective use of the *Ugunduzi* app due to lack of experience on using smartphone. During the survey, it was observed that most participants had a kind of fear on using the app thinking that they could damage the smartphone. It was also noted that it took a time to get in effective use of the app for those who had little experience of using smartphones, compared to few who had such experience.

Furthermore, from the study findings it was identified that, in all study areas there is a problem of weak network connectivity. Sharing information among users of the *Ugunduzi* app to the *Ugunduzi* website is one of the services provided by the app. Participants of the study expressed that the platform needs network services to enable downloading and sharing what you have with others and view what others posted to the website. However, participants from all study areas reported that the network connectivity problem in their areas posed a great challenge to effective use of this service. Participants explained that sometimes they needed to peruse at the *Ugunduzi* website for posting and viewing news. Unfortunately, they couldn't do that because of unavailability of the network. If it happened there was network connection, the speed was very weak which discouraged

using the service. The participants continued to explain that most users enjoyed using the service when they went to towns and cities where there are good network services. Therefore, when one went town for other issues, one would use that chance for perusing the *Ugunduzi* website using the *Ugunduzi* app. The situation is badly to Menge and Lubungo village in Lubungo ward of Mvomero District and Chambezi village of Chambezi ward in Bagamoyo District. *“In our area network is very low, I am not enjoying the Ugunduzi app, because sometime I need to share instant issue to my fellows, but I can't make due to low network. When I go town for other issues that is where I use the chance for perusing”* (Hamisi Shomary in Lubungo village during persona communication with researcher). The situation reduced the utilization of the *Ugunduzi* app. The network problem on using mobile apps was also reported by Navinkumar *et al.* (2018), Crespo *et al.*, 2020 and Kenny and Regan (2021) from their studies.

In additional, the study findings revealed that, inadequate electricity power supply is another challenge facing smallholder farmers within study areas. Electricity infrastructure plays a great role in supporting effective use of the *Ugunduzi* app. This study found that, in both areas in which this study was carried out, many people about 93% did not have electricity power supply in their homes. The participants in this study in all the study areas reported that most of them used to go out of their houses for charging their phones for using *Ugunduzi* app. On doing that, bad things could happen to their phones including the phones getting damage by people or children due to limited care, the phones could be stolen, and the phone might not be well charged. To avoid this situation, others paid for having their phones charged, which sometimes they failed to afford due to lack of money. This led to some phones for using the *Ugunduzi* app remaining without power and out of use for quite sometimes. The situations undermined effective use of the app. The results

correlate with ones by Navinkumar *et al.* (2018), Crespo *et al.* (2020), Kenny and Regan (2021) and Fox *et al.* (2021) who reported the same.

On top of that, costs constraints for sustainability on using the *Ugunduzi* app was another challenge reported could hinder effective use of the app. Results of this study revealed that there could be a low level of sustainability of using the app due to some factors including high costs of purchasing smartphone devices for using *Ugunduzi* app and running costs, especially on purchasing internet bundles. During discussions, participants reported that they had been given smartphones devices for using *Ugunduzi* app by the SWISSAID project. The project also supported them on running costs by providing them with internet bundles in each month which were enough to peruse the app for the whole month. The participants continued explaining by saying that, after identifying the challenge of power supply among many *Ugunduzi* app users, the project had purchased solar power for each participant for charging their phones. This means that the users of the *Ugunduzi* app were given support in all aspects by the donor. A question arose about what would happen after the donor ended. This may imply that few people would manage to continue using the *Ugunduzi* app if the project phased out. Therefore, the sustainability of using the app among many smallholder farmers could be very low. A similar challenge was also reported by Navinkumar *et al.* (2018), Crespo *et al.* (2020) and Kenny and Regan (2021) in their studies.

Table 3.1: Demographic characteristics of the respondents

Variable	Response	Frequency	Percent
Sex	Female	31	51.7
	Male	29	48.3
	Total	60	100
Age	36 and above	42	70
	18 to 35 Young age	18	30
	Total	60	100
Education	Basic/Primary education	48	80
	High level education	12	20
	Total	60	100
Smartphone ownership	Owners	12	20
	Non owners	48	80
	Total	60	100
Challenges in network	Challenged	52	86.7
	Non challenged	8	13.3
	Total	60	100
Have electricity power supply	Having	4	5.7
	Not having	56	93.3
	Total	60	100

3.3.4.2 Limitations from using Ugunduzi app

Findings from this study revealed that, *Ugunduzi* app use smartphones Android based with Google Chrome web browser. It was found that smartphone devices for installing *Ugunduzi* app should be an Android based operating system. In addition, during an interview session with one of the key informants in Masasi, Mr Fadhili Stambuli (2021), he reported that in the Android smartphone one should install Google Chrome web browser for downloading the *Ugunduzi* app. The key informant continued to explain that one can't manage to download and use the *Ugunduzi* app to a smartphone which uses other operating systems such as iOS, Bada, Tizen, Blackberry, Windows and Symbian. This means that if one wants to use the *Ugunduzi* app, one has to purchase a smartphone which is Android based and install a Google Chrome web browser in the device to manage to download and use the app. The same was reported by Kenny and Regan (2021) that most smartphone apps use Android based devices.

Ugunduzi app focuses on supporting agro-ecological practices for improving cropping system only. On observing what was in the *Ugunduzi* app, it was found that features which were available in the app were concerning improving soil management and pest control for better crop production. During discussions with farmers they reported that the *Ugunduzi* app was created purposefully for supporting farmers on record keeping and share information concerning cropping system only. The app does not suit other agro-ecological practices such as livestock keeping or forestry. This means that livestock keepers and foresters can't use the *Ugunduzi* app even if they apply agro-ecological approaches. These results differ from those reported by Dauma *et al.* (2018) and Crespo *et al.* (2020) that smartphones are suitable for both agricultural and other activities.

Besides, *Ugunduzi* app was designed to support farmers who know how to read and write. Therefore, the app is not suitable for illiterate farmers. On using the *Ugunduzi* app, it was found that users have to read the instructions and follow the process for getting services available in the app. In all activities where the app is intended to support farmers; including record keeping, sharing information and calculating costs used and benefits obtained on per plot bases; the users have to read what to do and write by following processes step by step. Therefore, for those who do not know how to read and write, it could be difficult to use the *Ugunduzi* app. This differs from a time tracker app reported by Dauma *et al.* (2018) which is suitable to be used by illiterate farmers because it uses pictures for taking and keeping records.

Additionally, *Ugunduzi* is a one way communication designed app. This study identified that, on sharing information, no feedback one can get after posting the information to the *Ugunduzi* website or viewing others posts. During discussions with farmer participants reported that, at the *Ugunduzi* website, you just share what you have and see what others

posted to the website for seeing and learning from senders of the information. There is no interaction between senders and receivers of the information. The participants continued to express that sometimes users of the app need more clarification on posts from senders of the information, or they need to ask questions to fellows due to some challenges they encounter from using agro-ecological practices, but they can't because there is no mechanism for interaction at the *Ugunduzi* website “*Sometimes I need some clarification support from my fellow farmers due challenge I encountered on using the agro-ecological practices for soil management or pest control, but I can't do that because no way to interaction in the Ugunduzi website*” (Zainabu Muhamed in Mbemba village (2021) during personal communication with researcher). Navinkumar *et al.* (2018) also reported the same limitation.

Not only that, it was also identified that the *Ugunduzi* app does not allow entering new inputs. The results from this study revealed that, in the *Ugunduzi* app, there are various names of agro-ecological practices for soil management, pest control and crops. Users have to choose information in the app for record keeping which includes types of crop production practices and agro-ecological practices used (soil management/pest control). During discussions, the participants reported that, if for example a crop whose production practices are needed is not available in the app, it is difficult to record that crop because the app will not allow entering a new crop which is not in the app. The situation is the same with the soil management and pest control; if one wants to enter a new name of soil management or pest control, one can't do that.

The results from the study also indicated that in using *Ugunduzi* app only photos and voice messages can be shared via the *Ugunduzi* website. Writing messages can't be shared. During discussion with farmers, they announced that even if the app allows

keeping records in the form of pictures, sound and written messages, but what users can share with others is only pictures and sound messages. Written messages remain as confidential information of the users. The participants continued to explain that the app can't allow video recording messages.

Table 3.2: Overview of the main themes and subthemes of the study

Theme	Sub theme
Challenges	Lack of practical experience of using smartphones
	Weak network connectivity
	Inadequate electricity power supply
	Costs constraints for sustainability on using the app
Limitations	Use only smartphones android based on Google chrome web browser
	Focus on agro-ecological practices for improving cropping system only
	Not suitable for illiterate farmers
	Is a one way communication app
	Only photos and voice messages can be shared
	It does not allow to enter new inputs

3.3.5 Conclusion and recommendations

Agricultural smartphone applications in developing countries including Tanzania have great potential of improving farming activities to increase productivity, especially in rural areas where more producers are smallholder farmers. The apps indicated cognitive support to farmers on various matters including record keeping, sharing agricultural knowledge and information and increasing networking among users. However, several obstacles have been reported to exist which hinder effective use of the apps among most farmers in developing countries, Tanzania in particular. On the other hand, some developers of such apps have tried to initiate apps which can suit socio-economic factors of particular areas. The findings of this study imply that there is a need for responsible

stakeholders including the government to take immediate actions to reduce the challenges observed through various studies to improve farming activities via digital tools. App developers should learn via previous studies before new initiative in order to develop suitable apps which cope with particular population environments. The recommendations are.

1. The Government of Tanzania, through the responsible ministry, is urged to find a way of reducing the challenges observed in this study for improving farming activities, agro-ecological practices in particular.
2. App developers have to check the limitations identified through this study and look into the possibility of developing suitable technologies by considering needs of the intended population.

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3.4 Manuscript 2

The effects of cow dung and poultry manure in crop yield: Observation from farmer-led research

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3.4.1 Abstract

The aim of this study was to investigate the effect of crop yield from farmer-led research on agro-ecological practices focusing on cow dung and poultry manure with the rates which are manageable by farmers. Masasi, Mvomero and Bagamoyo Districts of Tanzania were used as case studies. Sixty smallholder farmers, 20 in each study area were selected to participate in the study. Data from the field were collected through field visits and using *Ugunduzi* app in which farmers used to keep records. A structured questionnaire was used to collect quantitative data. Qualitative data were collected through focus group discussions. Quantitative data were analysed using SPSS program, excel and R-software. Qualitative data were analysed using content analysis technique.

The results indicate that there was positive significant effect in yield due to applying cow dung and poultry manure with the farmers' rates. The maximum average rates of cow dung and poultry manure applied by farmers brought positive effect in yields were 2.4t/ha and 1.7t/ha respectively for Masasi farmers, 3t/ha and 4.7t/ha respectively for Mvomero farmers and 3.5t/ha and 3.7t/ha respectively for Bagamoyo farmers. From the results it is recommended that, Government through responsible ministry and NGOs, should promote agro-ecological practices of cow dung and poultry manure to be used by farmers as one among strategic approaches for increasing crop yield. Encouraging investment in agro ecological practices, particularly cow dung and poultry manure should be done to ease availability of inputs. More farmer-led research should be conducted to identify other beneficial agro-ecological practices to smallholder farmers.

Key words: Crop yield, farmer-led research, agro-ecological practices, cow dung manure, poultry manure, smallholder farmers

3.4.2 Introduction

Farmer-led research refers to an approach of empowering community to engage in the research tasks of identifying profitable agricultural technologies (Fioret *et al.*, 2018). The research provides an opportunity to farmers to be part of the investigation. It increases chances of adoption of the identified technology (Sieglinde *et al.*, 2019). Farmer informal research is the origin of this kind of research in which farmers themselves think on what to investigate and methodology to use in order to reach required objective (Kummer *et al.*, 2017). However, in farmer-led research other actors include researchers, extension officers, and donors could come in for providing advisory services on research activities and other issues including financial support (Gaba & Bretagnolle, 2020). This study

focused on farmer-led research of agro-ecological practices, particularly cow dung and poultry manure, for improving crop yield.

Agro-ecological practices comprise natural resources based which can be applied in livestock keeping, forestry and cropping systems (FAO, 2014). This study relies on agro-ecological practices for improving cropping system. Several studies reveal that agro-ecological practices could be a problem solver to smallholder farmers in improving crop yield on the face of climate change (Mdee *et al.*, 2019; Wezel *et al.*, 2020). According to FAO and ECA (2018), climate change is among of great sources of the declining crop productivity which leads to food insecurity among many smallholder farmers. Agro-ecological practices consider ecosystem services to reduce environmental pollution for climate change resilience. The approaches rely on natural resources rather than external inputs for sustainable agriculture to meet food demand (Schoonhoven & Runhaar, 2018).

Cow dung and poultry manure are among of the agro-ecological practices pointed out by several studies that can improve soil quality and bring positive effects in yields of various crops (Adeniyani *et al.*, 2011; Ulzen *et al.*, 2020; Eleduma *et al.*, 2020). High nutrients and organic matter contents in cow dung and poultry manure could be among the preferable factors for high productivity performance (Eleduma *et al.*, 2020). However, most previous studies on these practices have been done by scientists focusing on effects of many issues including soil pH, soil acidity, plant heights, increasing of nutrients, organic carbon, phosphorus, calcium and yield (Zaman *et al.*, 2017; Eleduma *et al.*, 2020). High application rates ranging from 5t/ha to 20t/ha are among of the recommendations provided from their studies (Adeniyani *et al.*, 2011; Usman, 2015; Zaman *et al.*, 2017; Eleduma *et al.*, 2020).

In practice, these rates are too high to be achieved by most of Tanzanian smallholder farmers who are the focus of this study. This is because most smallholder farmers in Tanzania who engages in agricultural activities do not keep livestock from which these inputs have to be obtained (URT, 2021). Therefore, there is a need for preferable mechanism which can capture the rates of inputs farmers can manage to achieve and looking few elements which seem could motivate farmers. Farmer-led research revealed to fit this case in the sense that it keeps farmers free to practice what they want and what they can (Nain *et al.*, 2018). Most farmers are happy with the technologies which improve yields with low costs; this study focused on looking in to the effect in crop yield from farmer-led research on agro-ecological practices of cow dung and poultry manure with the rates applied by farmers. The results could provide insight about the performance of cow dung and poultry manure on improving crop yield in a real situation of Tanzanian smallholder farmers. The results will also contribute to other goals of finding best practices for improving crop yield to reduce food deficit problem among Tanzanian smallholder farmers and elsewhere. Contribution to the literature of the related works was also the goal of this study.

Study hypotheses

- (i) There is positive significant effect in crop yields when smallholder farmers apply cow dung manure for soil management
- (iii) There is positive significant effect in crop yields when smallholder farmers apply poultry manure for soil management

Literature review and theoretical framework of the study

In the last few decades African farming has experienced a series of challenges including soil quality degradation and unreliable rainfall caused by climate change disaster (Gashu

et al., 2019). On this scenario most poor rural smallholder farmers have been left with food deficit due to shrinking on crop productivity (FAO, ECA and AUC, 2020). Promoting conversional farming to increase crop yield in order to meet food demand was among the strategies taken by many of the African countries including Tanzania (Thoma, 2019). However, the efforts taken have brought less effect on reducing hunger in Tanzania. The food deficit problem continues to exist yearly among poor rural farmers (MUCHALI, 2017). High costs, low knowledge and poor use of agro-chemical inputs among many smallholder farmers, contribute to continuous poor crop yield (Nonga *et al.*, 2011; Lema *et al.*, 2019). Furthermore, the inputs have been debated worldwide as one of critical threats to environment and source of soil quality degradation which in turn lead to frequent low crop harvesting (Joko *et al.*, 2017; Zhang *et al.*, 2018; Meena *et al.*, 2020).

Several agricultural practitioners and development actors came up with the idea of transforming the farming system to have a strong one which can cope with climate change to revamp soil quality for boosting productivity performance (Carlos *et al.*, 2015; Chizallet *et al.*, 2018; Ajena *et al.*, 2020). It was remarked that agro-ecological approaches including cow dung and poultry manure could be best-fit measures to smallholder farmers as they improve soil quality for increasing production without harming environment (Adeniyani *et al.*, 2011; Usman, 2015; Zaman *et al.*, 2017; Eleduma *et al.*, 2020; Ulzen *et al.*, 2020). Therefore, conducting research for understanding workability of the practices on the real ground is crucial. This was the essence of coming up with the farmer-led research. The aim was to have vivid evidence on the idea that agro-ecological practices could contribute to improving crop yield using the application rates which smallholder farmers can manage to achieve.

The study was guided by the Theory of Change in African Agriculture (TCAA) by Adekunle and Fatunbi (2014). The theory of change describes how a given intervention, or set of interventions, is expected to lead to specific development change. It describes the process of social change by making explicit the perception of the current situation (Adekunle and Fatunbi, 2014). Tanzanian smallholder farmers could make changes in production system from current conventional yield based farming to agro-ecological sustainable farming for sustainable environmental protection and yield production improvement. Agro-ecological practices of cow dung and poultry manure have been used as an intervention to the intended goal.

3.4.3 Research methodology

The study was carried out in Masasi, Mvomero and Bagamoyo Districts of Mtwara, Morogoro and Coast regions respectively. Availability of scientific trials whereby several agro-ecological practices had been carried out was the main reason for selecting the areas. The trials support farmers to learn and choose some for trying in their fields. This study focuses on smallholder farmers who applied cow dung or poultry manure for soil management to increase crop yield.

One ward in each study area was randomly selected based on the extent of closeness to the scientific research plots. The assumption was that nearby wards could help participants to go and learn from scientific research trials easily. Sixty smallholder farmers, 20 in each selected ward and who conducted experiments on cow dung and poultry manure were randomly selected to participate in the study.

3.4.3.1 Data collection

Time series research method was used in this study. The method allows data of a single subject from the same location to be collected repeatedly over a period of time at regular intervals (Velicer & Fava, 2003). Three research seasons of 2019, 2020 and 2021 were conducted for investigation of the effects in crop yield of cow dung and poultry manure with the rates applied by farmers. In all the seasons smallholder farmers were advised to apply the manure as much as they could to improve productivity.

Quantitative and qualitative primary data were collected during the survey. Participants used *Ugunduzi* app to collect quantitative data from the research field and keep records. The *Ugunduzi* app is a smartphone based app which was developed to support farmers on agro-ecological research for data collection and record keeping. Individual interviews by using a structured questionnaire and observation technique through field visits were also used to collect quantitative data. During the study period field visits and research supervision were carried out at least 3 times per season. The visits were conducted at the beginning of the season to help the researcher on planning and sizing of the research plots. Mid-season field visits were conducted to see development of the research plots, and at the end of the season to help weighing research crop products. The data helped to reduce errors which could be made by farmers by correlating what was written in the app, data from farmers' individual interviews and field observations. Quantitative data provide measurable evidence if there was significant effect on crop yield from using the practices.

Three focus group discussions one in each study area, were conducted to collect qualitative data. Qualitative data explain in detail what was observed in quantitative data. Data from key informants such as research projects officers were collected through individual interviews. The aim was to understand how farmers had received training on

the practices and their knowledge on agro-ecological practices. Secondary data were collected from libraries, internet and various reports of agro-ecological practices from different civil society organisations and government. Secondary data provide information of what was there concerning agro-ecological practices cow dung and poultry manure in particular.

3.4.3.2 Data analysis

Statistical package of Social Sciences (SPSS) programme version 26 was used to analyse quantitative data. Descriptive statistics and cross tabulation were used to analyse frequencies and percentages of quantitative data. Microsoft excel was used to find average yields between treatments and control plots from field results. Analysis of Variance (ANOVA) using R-Software was used to measure the effects in crop yield between treatments and control plots for testing the hypotheses of the study. Qualitative data were analysed by using content analysis in which collected data were described and coded to identify themes for interpretation.

3.4.4 Findings and discussion

3.4.4.1 Findings from the field

Despite 60 smallholder farmers have been selected to participate in this study, not all the selected farmers participated fully in all the research seasons. This is due to some reasons including delaying in research plots preparation, family issues and death. In 2019 research season only 47 smallholder farmers participated. In 2020 only 56 farmers participated, and 50 farmers participated in 2021 from all study areas (Table 3.3).

During the study, participants were free to plan their own research including treatments to test, size of the research plot to develop and kind of crop to grow. One participant could

conduct research on either cow dung manure, poultry manure or both in different plots using one crop of interest. Therefore, a farmer could develop two or three plots in which one could be control plot for comparing yield results with the treatments plot(s) for the same crop of interest. A participant could also be free to change treatments in different research seasons. In 2019 a total of 107 research plots were developed from all study areas in which 36 plots were treated with cow dung manure, 27 with poultry manure and 47 were control plots. A total of 121 plots were developed in 2020, from which 42 were treated with cow dung manure, 23 with poultry manure and 56 were control plots. For 2021 a total of 104 plots were developed in which 36 were treated with cow dung, 18 with poultry manure and 50 were control plots.

The participants in the research were also free to choose the size of plot to develop. Emphasis was to make sure the plots had control and treatment of equal size. During the study period, the maximum research plot size for Masasi participants was 2 000 square metre (m^2) and the minimum size was 80 m^2 . For Mvomero study area the maximum plot size was $1\,300 \text{ m}^2$ and the minimum size of the trial plot was 80 m^2 . In Bagamoyo the maximum plot size was $1\,000 \text{ m}^2$ and minimum trial plot size was 100 m^2 .

During the study, participants were encouraged to apply the treatments as much as they could for better production. The application rates may differ between study areas, research seasons, treatments, and between farmers. This depends on availability of the treatments, costs of the treatments transport costs and soil quality of the area. For instance, in the 2019 research season, the average application rates of cow dung and poultry manure for Masasi participants were 2.4t/ha and 1.7t/ha respectively. For Mvomero participants, the average application rates of both cow dung and poultry manure in 2019 was 3t/ha. In Bagamoyo the average rate applied by participants in 2019 for cow dung was 3.6t/ha and 3.9t/ha for poultry manure. In 2020 the rates were changed in which 2.6t/ha and 2.9t/ha of

cow dung and poultry manure respectively were applied by participants from Masasi; 3.2t/ha and 4.3t/ha of cow dung and poultry manure respectively were applied by participants from mvomero; and 3.7t/ha of both cow dung and poultry manure applied by participants from Bagamoyo. In 2021 the average rate of both cow dung and poultry manure applied by farmers in Masasi was 2.6t/ha. For Mvomero the average rates were 3.6t/ha and 4.7t/ha for cow dung and poultry manure respectively while in Bagamoyo the average rates of cow dung and poultry manure applied in 2021 were 4.1t/ha and 3.7t/ha respectively (Table 3.3).

Table 3.3: Findings from the field

Year	Study area	Participants	Number of plots				Average rates in t/ha		Plot size in m ²	
			Cow	Poultry	Control	Total	Cow	Poultry	Max	Min
2019	Masasi	16	8	11	16	32	2.4180	1.6999	2000	80
	Mvomero	15	14	7	15	36	3.0662	3.0067	1300	80
	Bagamoyo	16	14	9	16	39	3.5957	3.8874	1000	100
	Total	47	36	27	47	107				
2020	Masasi	20	10	10	20	40	2.6799	2.9131	2000	80
	Mvomero	18	17	6	18	41	3.2076	4.3206	1300	80
	Bagamoyo	18	15	7	18	40	3.6899	3.7397	1000	100
	Total/Average	56	42	23	56	121				
2021	Masasi	18	12	6	18	36	2.6130	2.5858	2000	80
	Mvomero	16	11	7	16	34	3.6080	4.7141	1300	80
	Bagamoyo	16	13	5	16	34	4.1156	3.7049	1000	100
	Total/Average	50	36	18	50	104				

3.4.4.2 Yield results in kg per participant

In each season yield data were collected from each participant. During harvesting period the researcher assisted farmers to weigh the produce and collect the data of the harvest. The data were also drawn from *ugunduzi* app which farmers used to keep records. The yield results from treatments which were cow dung and poultry manure together with control plots from each participant in all the study areas are indicated in Table 3.4.

Table 3.4: Yield results per participant in kg

Year	Masasi			Mvomero			Bagamoyo		
	Control	Cow	Poultry	Control	Cow	Poultry	Control	Cow	Poultry
2019	36.00	-	54.00	14.00	15.00	-	19.00	25.00	29.00
	12.00	-	25.00	120.00	250.00	-	18.00	30.00	22.00
	51.00	62.00	-	7.00	-	10.00	26.00	31.00	20.00
	8.00	13.00	15.00	5.00	7.90	-	16.00	26.00	23.00
	3.00	-	5.00	14.00	25.00	20.00	10.00	12.00	16.00
	3.00	-	1.50	5.00	5.00	-	4.00	6.00	7.00
	26.00	32.00	-	340.00	720.00	-	16.00	25.00	-
	36.00	-	65.00	40.00	60.00	100.00	25.00	-	35.00
	160.00	320.00	-	80.00	70.00	-	8.00	12.00	-
	45.00	85.00	-	6.50	14.00	8.00	90.00	180.00	-
	.50	1.50	2.00	2.00	5.00	-	20.00	32.00	-
	36.00	-	72.00	25.00	32.00	28.00	8.00	12.00	-
	1.00	1.50	2.00	30.00	45.00	32.00	24.00	36.00	26.00
	32.00	46.00	-	12.00	20.00	18.00	12.00	21.00	-
	60.00	-	125.00	7.00	12.00	10.00	20.00	28.00	-
	18.00	-	27.00				9.00	12.00	10.00
	2020	31.00	-	48.00	6.00	11.00	-	8.25	-
23.00		-	32.00	120.00	250.00	-	3.60	1.22	-
51.00		62.00	-	5.00	-	10.00	20.00	16.00	-
8.00		13.00	-	5.00	10.00	-	17.05	5.60	15.00
3.00		-	5.00	14.00	22.00	22.00	12.00	10.00	-
3.00		2.00	-	22.00	32.00	32.00	6.00	4.00	6.00
26.00		32.00	-	340.00	720.00	-	25.00	16.00	22.00
4.00		-	4.00	40.00	60.00	-	25	-	35.00
160.00		320.00	-	80.00	70.00	-	12.00	8.00	10.00
45.00		85.00	-	6.50	19.50	-	90	-	180.00
.50		1.50	-	2.00	5.00	8.00	32.00	20.00	-
8.00		-	15.00	25.00	25.00	20.00	12.00	8.00	-
1.00		1.50	-	32.00	45.00	-	36.00	24.00	-
32.00		46.00	-	12.00	20.00	-	21.00	12.00	-
3.00		-	1.50	5.00	13.00	-	28.00	20.00	-
1.00		-	1.00	34.00	50.00	-	70.00	56.00	-
22.00		-	32.00	16.00	28.00	-	12.00	8.00	-
16.00	-	22.00	32.00	48.00	48.00	32.00	44.00	-	
14.00	16.00	-							
37.00	-	45.00							
2021	50.00	80.00	-	8.00	13.00	12.00	20.00	-	34.00
	17.00	-	19.00	80.00	130.00	-	22.00	36.00	-
	30.00	37.00	-	11.00	17.00	-	16.00	20.00	-
	26.00	60.00	-	38.00	50.00	-	6.00	17.05	12.00
	20.00	-	34.00	5.00	8.00	9.00	5.00	8.00	-
	4.00	-	5.00	24.00	28.00	-	7.00	10.00	9.00
	17.00	18.00	-	120.00	220.00	-	1.50	-	3.00
	240.00	400.00	-	8.00	12.00	-	6.30	15.40	-
	3.00	-	4.00	60.00	90.00	-	16.00	19.50	-
	3.00	2.00	-	38.00	65.00	-	20.00	40.00	-
	3.50	5.00	-	32.00	40.00	-	1.00	2.20	-
	32.00	46.00	-	26.00	-	59.00	48.00	60.00	-
	46.00	-	80.00	34.00	-	50.00	12.00	21.00	-
	22.00	-	32.00	113.00	-	154.00	20.00	28.00	-
	4.00	10.00	-	8.00	-	13.00	10.00	25.00	-
	75.00	105.00	-	40.00	-	60.00	26.00	-	59.00
	96.00	152.00	-						
6.00	8.00	-							

3.4.4.3 Results of testing the hypotheses of the study

To understand if there is any significant effect in yields when smallholder farmers applied cow dung and poultry manure for soil management, analysis was done by applying one way analysis of variance (ANOVA) using R-software. Analysis on average yield of treatments which are cow dung and poultry manure with their control plots in each season was done. The aim was to test theoretical hypotheses from farmer-led research perspective.

Hypothesis 1: Testing the effect in crop yield from applying cow dung manure

On testing the effect on crop yield of cow dung manure applied by smallholder farmers, the results from the analysis had showed that there was strong positive significant effect in yield with p-value 0.001 in all the three seasons in all the study areas. Even if the average applications rates differed between the study areas, effect on yield was observed in all the areas of the study. For Masasi the average rates of cow dung manure applied by smallholder farmers ranged from 2t/ha to 3t/ha in all the research seasons while for Mvomero they ranged from 3t/ha to 4t/ha and for Bagamoyo, the rates ranged from 3.5t/ha to 4.5t/ha. During focus group discussions with farmers in Masasi in which the rates were low compared to others, participants reported that it was difficult to get high volume of cow dung manure because in their area there were a few people who kept cattle. They continued to express that they preferred to use cow dung manure even if in small amounts because they had identified that the manure was good and sustainable. Cow dung manure is sustainable in the sense that, when you apply it in your plot this season, it can also work in the next season. *“In Masasi, to get cow dung manure is difficult because few people keep cattle, but I like to apply it because when I use it in this season it can also work in the next season. So when I apply it now even if I fail to get it in the coming season I can have hope of getting some good yield results”* (Salum Abdallah

a participant farmer from Chigugu, Masasi in 2021. The sustainability of cow dung manure was also reported by participants from Mvomero and Bagamoyo study areas during focus group discussion. It was also reported by Usman (2015), Zaman *et al.* (2017) and Eleduma *et al.* (2020) from their studies. This could imply that when cow dung manure is used by smallholder farmers it may change their income and livelihood in general due to better crop yield results.

Hypothesis 2: Testing the effect in crop yield from applying poultry manure

On testing performance of poultry manure applied by smallholder farmers in the research- led by them for improving crop yield, the results from the analysis showed that there was strong positive significant effect in yield observed from Masasi trials in all the research seasons. The average rates applied in the trial plots by farmers in Masasi ranged from 1.7t/ha to 3t/ha. Strong positive effect in yield was also observed from Bagamoyo trials for the first and second seasons (Table 3.5). Moderate positive effect was observed in the third season. The average rates of poultry manure applied by farmers in Bagamoyo ranged from 3.7t/ha to 3.9t/ha. For Mvomero trials on poultry manure the results from analysis indicated that there was slightly positive effect in crop yield on using poultry manure in the first season, moderate effects in the second season but strong positive effect in the third season. The average application rates were 3t/ha, 4.3t/ha and 4.7t/ha for the first, second and third seasons respectively. This observation may indicate that, as you increase volume of manure, there is increased performance in yield. This could imply that using poultry manure is a better approach in Mvomero at a high rate of the manure. Generally, from all the study areas observations, it was found that, poultry manure is among the best practice for increasing crop yield. The effectiveness of poultry manure in yield was also reported by Adeniyani *et al.* (2011).

Furthermore, during focus group discussions with participants in Mvomero and Bagamoyo they reported that using poultry manure is a good practice because it works quickly after applying it to the soil but it is not sustainable. Farmers who participated in this study reported that poultry manure can work for 2 to 3 months and then start to lose its power; it requires users to re-apply it if one wants to get good harvests. *“Using poultry manure is a good practice because it performs quickly; you can see the effect in a few days after application, but it loses the power after 2 or 3 months; so it needs to re-apply for better yield performance”* (Nuru Mohamed a participant from Bagamoyo, July, 2021). Participants reported that using poultry manure is a good practice for crops which take a short time to be ready for harvesting, like vegetable crops. Participants continued to express that using poultry manure also is a good approach to be used as a booster. This means that, after applying other types of manure during planting, you can use poultry manure at the middle of farming for boosting crop growing.

Table 3.5: Testing hypotheses of the study

Year	Trials	Study area	Average yields in kg		Mean Square	F-value	P-Value
			Treatment	Control			
2019	Cow dung manure	Masasi	70.13	40.44	24083	813.6	0.000 ***
		Mvomero	91.49	50.04	468289	648.2	0.000 ***
		Bagamoyo	32.53	20.00	24083	813.6	0.000 ***
	Poultry manure	Masasi	35.77	19.41	15090	341.8	0.000 ***
		Mvomero	23.33	16.67	881.5	15.48	0.017 *
		Bagamoyo	29.00	21.22	1258.7	108.4	0.000 ***
2020	Cow dung manure	Masasi	57.90	34.05	82041	444.2	0.000 ***
		Mvomero	84.03	46.56	470866	470866	0.000 ***
		Bagamoyo	22.58	16.85	3192	72.6	0.000 ***
	Poultry manure	Masasi	20.45	14.20	3014.1	163.9	0.000 ***
		Mvomero	26.29	14.50	5886	35.15	0.0019 **
		Bagamoyo	41.90	22.32	22406	270.3	0.000 ***
2021	Cow dung manure	Masasi	76.92	48.54	136225	1494	0.000 ***
		Mvomero	61.18	38.55	41296	528.3	0.000 ***
		Bagamoyo	23.24	14.53	2479.6	85.05	0.000 ***
	Poultry manure	Masasi	29.00	18.67	3853	185.2	0.000 ***
		Mvomero	51.00	33.43	15091	192.1	0.000 ***
		Bagamoyo	23.40	11.90	2028	58.02	0.0047 **

Effects:- *** strong effect, ** moderate effect, * small effect

3.4.5 Conclusion and recommendation

The aim of this study was to investigate if there was any significant effect in crop yield on applying agro-ecological practices with the rates which are manageable by farmers. From the study findings it is concluded that if cow dung and poultry manure were more used, there could be more yields. In addition, if the inputs could be easily acquired, most farmers could be encouraged to apply agro-ecological practices, cow dung and poultry manure in particular. The results fostering the argument of theory of change that, in a given any intervention, or set of interventions, could lead to a specific development change. Based on the theory of change agricultural stakeholders suggests smallholder farmers to make a change by shifting to agro-ecological farming system. From the results the following were recommended.

1. Government through responsible ministry and NGOs to promote agro-ecological practices of cow dung and poultry manure to be used by farmers as among of strategic approaches for increasing crop yield.
2. Encouraging investment on agro ecological practices particularly cow dung and poultry manure to easing availability of inputs.
3. More farmer-led research should be conducted to identify other beneficial agro-ecological practices to smallholder farmers

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CHAPTER FOUR

4.0 GENERAL DISCUSSION

4.1 Factors Influencing Smallholder Farmers to be Engaged in FLRAG

The study findings revealed that less experienced farmers have greater chances to be engaged in farmer-led research. This could imply that farmers in this group value new ideas and still have energy of finding benefits through new opportunities. The situation may differ from that of their counterpart group who have already got several opportunities; the perception of this group may be 'nothing is new'. The same findings were reported by Nahayo *et al.* (2017) and Murendo *et al.* (2019) from their studies, but the findings contradict with ones by Akinmusola *et al.* (2016). Also, the findings from this study showed that smallholder farmers who are motivated to practise after receiving theoretical knowledge have higher chances of being involved in farmer-led research than those who have not such characteristics. The plausible indication of the results is that individual behaviour may influence development of certain activities within a particular group of people. The findings are in line with ones by Kummer *et al.* (2017). In addition, the results from the study indicated that easy access to agro-ecological inputs could influence smallholder farmers to participate in research activities. This may imply that, if farmers easily obtain the required technology, it will encourage them to try to improve farming activities. The results reported by Murendo *et al.* (2019) also indicated the same. Furthermore, the findings from this study showed that smallholder farmers who own a big piece of land of more than 2.2 hectares have high chances to be part of farmer-led research than those who own smaller pieces of land. The results could indicate that owning enough resources may influence involvement in development activities. The results similar with the findings reported by Kummer *et al.* (2017), Nahayo *et al.* (2017) and Murendo *et al.* (2019) from their studies.

4.2 Examining Continuance Intention of Using the Ugunduzi app

Examination was done by testing theoretical hypotheses of the study. Perceptions on the usefulness, easiness of use and user satisfaction of the app were tested. Technological Acceptance Model (TAM) and Expectancy Continuation Theory (ECT) were applied to guide this paper. The results indicated that there was a strong positive relationship between perceived usefulness and user satisfaction. During focus group discussion with farmers, participants in this study expressed that the app enabled them to identify suitable agro-ecological practices through records kept in the app. The participants continued to explain that their future plans of farming activities could be well set using the records kept in the app. On top of that, the *Ugunduzi* app supports knowledge sharing particularly agro-ecological practices knowledge via the *Ugunduzi* web site in which users share information. Furthermore, the participants reported that the app may encourage production improvement due to competition involved in the *Ugunduzi* website. They said that, at the website, farmers have a tendency of competing to post most success results from their fields. Therefore, the participants were working hard to post successful work, hence production improvement. The results concur with those reported by Tisselli (2016), Capalbo *et al.* (2017), Daum *et al.* (2018) and Crespo *et al.* (2021).

On the other hand, the results didn't show any relationship with the perceived easiness of use to user satisfaction of the *Ugunduzi* app. During a focus group discussion session with farmers, the discussants argued that there were processes in the app which needed users to perform to reach what they wanted to do. They continued to report that those processes sometimes confused users. Generally, the findings indicated that smallholder farmers perceived the *Ugunduzi* app as a useful tool to them, but there were some efforts to be used to manage effective use of the app. This may imply that users of the *Ugunduzi* app were more satisfied with using the app due to its usefulness rather than its easiness of use.

The results are similar to the findings reported by Okoroji *et al.* (2021) from their study but contradict with the results by Daum *et al.* (2018) and Crespo *et al.* (2021).

On the side of testing continuance intention of using the *Ugunduzi* app among smallholder farmers in study areas, it was found that there was strong positive correlation between user satisfaction and using the *Ugunduzi* app with continuance intention of using it. However, the results showed indirect positive relationship between perceived usefulness and continuance intention of the app via user satisfaction. Furthermore, the results indicated that there was slightly indirect positive relationship between perceived easiness of use to the continuance intention of using the app via user satisfaction. This could indicate that the app may continue to be used by farmers as they were satisfied with its usefulness. Concerning easiness of use, the results may imply that, through training, individual spirit of learning and understanding, experience, encouragement and support from stakeholders could motivate many farmers to use the app and continue using it. The results are similar to ones reported by Irani (2000), Bhattacharjee (2001) and Alambaigi and Ahangari (2016).

4.3 Challenges and Limitations from Using Ugunduzi app

From the study, several challenges were identified which hinder effective use of the *Ugunduzi* app. The challenges included inexperienced smartphone use among most smallholder farmers. From the findings it was observed that most smallholder farmers in the study areas were not using smartphones before the introduction of the *Ugunduzi* app. The situation made most of them to fear using the app effectively thinking that they might damage the phones. Another challenge observed from study findings was low network connectivity. On sharing information through the *Ugunduzi* app, it needed to be connected to the network. It was revealed from this study that most study areas experienced low network connectivity which hindered effective use of the *Ugunduzi* app. Inadequate

electrical power supply was another challenge observed from this study. The challenge impeded effective use of the *Ugunduzi* app, especially on charging phones for using the app. Cost constraints for purchasing smartphone devices for using the *Ugunduzi* app and running costs, especially on purchasing airtime bundles, was another challenge which hindered effective use the *Ugunduzi* app technology and limited sustainability on using the app. Generally, the findings could indicate that, even if app developers could initiate very suitable apps for farmers, smallholders in particular, to support their farming activities, the environment of using the technology could undermine the efforts. The results are in line with ones by Navinkumar *et al.* (2018), Crespo *et al.* (2020), Kenny and Regan (2021) and Fox *et al.* (2021) who reported the same from their studies.

On the issue of limitations, it was found that the *Ugunduzi* app developers focused on supporting literate smallholder farmers who at least know how to read and write on their agro-ecological cropping practices. The developer were interested in smartphones Android based devices with Google Chrome web browser to be used by the app. Kenny and Regan (2021) also report that Android smartphones are used by many app developers as they are easy to operate. The *Ugunduzi* is a one way communication app which uses image and audio messages for sharing information.

4.4 The Effects of Cow Dung and Poultry Manure on Crop Yield

The findings from the study demonstrated that both cow dung and poultry manure had positive effects on increasing crop yields. However, from focus group discussions, participants expressed that cow dung manure could sustain the soil for a longer time compared to poultry manure. They continued to report that poultry manure is the best organic fertilizer for crops which take a short term to harvest like vegetables because the manure can work quickly and for short time it start to reduce the power. Poultry can take 2 to 3 months before the power of dung manure starts to go down and need re-application

for better performance of the crops. The manure also is a good practice to be used as a booster, meaning that users can use other manure types during planting and at the middle of the crop growing; users can apply poultry manure for boosting growing crops. On the other hand, the situation differs from cow dung manure. The participants in this study reported that, when you apply cow dung manure this year, its power can also work in the next season, meaning that the effect of cow dung manure can exist in the soil for a longer time, compared to poultry manure. The effectiveness of cow dung and poultry manure was also reported by Adeniyani *et al.* (2011), Usman (2015) and Zaman *et al.* (2017) in their studies.

4.5 Contribution of the Study

Generally, the study contributes to literature by describing the factors that influence smallholder farmers to be engaged in research activities, including farmer-led research. The study supports the factors such as personal attribute which includes experience, socio-economic factors including land size ownership and availability of technology which could have some influence on development changes. On the other hand, the study contributes on supporting the argument that the TAM, with its original constructs of perceived usefulness and perceived easiness of use in combination with ECT, could predict user satisfaction of the technology and its continuation of using. Furthermore, the study demonstrated challenges hindering effective use of the smartphone apps, *Ugunduzi* in particular and apps limitations. From the study findings, key stakeholders could be informed of the real situation of smallholder farmers in using digital tools in the current world that is full of digital technologies. In addition, the study contributes to the theory of change which emphasizes that sometimes it could reach a point of need a major system change for development. African farming system needs to be changed from agro-chemical yield based technologies to agro-ecological sustainability production based.

CHAPTER FIVE

5.0 GENERAL CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study was conducted focusing on examining the *Ugunduzi* app for validating its potential to smallholder farmers. Through the theory that was used to guide this study, which is TVT and parameters set to examine its performance for validation, it is concluded that the *Ugunduzi* app has greater potential to smallholder farmers who apply agro-ecological practices. From the study findings the app indicated its usefulness for supporting farmers to identify profitable agro-ecological practices through quality records kept in the *Ugunduzi* app. Future season farming plans could be easily set by looking at indicators from past farming activities through records kept in the app. In addition, agro-ecological knowledge has increased among smallholder farmers in study areas through sharing agro-ecological information at the *Ugunduzi* website via the *Ugunduzi* app.

On the other hand, by using the *Ugunduzi* app, the study findings revealed some processes to follow which somewhat discourage users especially at the early stage of using the app. However, with time through training, experience with using the app and encouragement to use it without fear, many users managed to use the app effectively. In addition, several challenges have been identified on using the *Ugunduzi* app which could hinder its effective use. Therefore, if effective measures have to be taken to reduce all obstacles to the effective use, the app could have greater contribution to improving food production among smallholder farmers. Furthermore, the study findings revealed that there are strong positive results on crop yield when smallholder farmers apply agro-ecological practices, cow dung and poultry manure in particular. Therefore, if the practices could be promoted to be used by many farmers, crop production could increase among smallholder farmers.

On top of that, the study identified that availability of agro-ecological inputs encourage many farmers to apply agro-ecological practices in their farming activities. On conducting FLRAG selecting committed participants are urged to set reasonable criteria by considering identified factors influencing farmers to participate in FLRAG

5.2 Recommendations

From the study findings, it is recommended that key stakeholders, including the Ministry of Agriculture, should do the following:

1. Key stakeholders including service providers of network and electricity power supply should work on reducing the challenges of low network and unconnected power in the study areas and other parts of Tanzania which face the same challenges. In addition, the government of Tanzania is urged to reduce costs of purchasing smartphone devices and promote their usage due to their usefulness, including using the *Ugunduzi* app.
2. The government of Tanzania, through its Ministry of Agriculture and NGOs dealing with agro-ecology are urged;-
 - To promote the use of *Ugunduzi* app in FLRAG for quality research results of identifying best practices which could increase crop production.
 - To promote the use of agro-ecological practices by many farmers, cow dung and poultry manure in particular as among strategic approaches for increasing crop yield.
 - To encourage more FLRAG for identifying more beneficial practices to smallholder farmers. Furthermore, on selecting participants identified factors

have to be taken into consideration on setting criteria for selecting participants of FLRAG.

3. Investors are encouraged to invest in agro-ecological practices particularly cow dung and poultry manure to mitigate the shortage of agricultural inputs.

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APPENDICES

Appendix 1: Questionnaire for baseline survey

Dear participants: This survey is for collect information to identify factors influencing smallholder farmers to engage in collaboration research with a researcher on the angle of agro-ecological practices. The aim is to use such factors in developing some beneficial criteria on selecting participants who will take their full responsibilities to the study. We therefore kindly request you to respond according to questionnaire as honestly as you can.

1. Date of interview
2. District respondent come from.....
3. Name of respondent.....Mob
4. Age of respondent.....
5. Gender of respondent
 - (a) Male
 - (b) Female
6. Education level of the respondent
 - (a) Primary School level of education
 - (b) Secondary school level of education
 - (c) College level of education
 - (d) University level of education
 - (e) No formal Education
7. Number of household members
8. Experience: Number of years in agricultural activities

Farmer-led research by definition is an action research taken by farmers on their own farms with close collaboration of researchers/agricultural experts. After understanding the meaning

9. Are you aware of this kind of research?
 - (a) Yes
 - (b) No
10. Are you aware of agro-ecological practices
11. Have you gotten any training on agro-ecological practices?
 - (a) Yes
 - (b) No
12. After getting training on agro-ecological practices did you tried to practice according knowledge you have gotten on training?
 - (a) Yes
 - (b) No
13. How do you see the easiness of getting agro-ecological inputs
 - (a) Easy
 - (b) Not easy
14. What is your farm size in acre do you usually cultivate per year
15. What is your owned farm size in acre
16. What is your rented farm size in acre
17. Are the markets of agro-ecological products available?
 - (a) Yes
 - (b) No
18. How do you see the market price of agro-ecological products
 - (a) High
 - (b) Normal like others
19. How do you see cost of production of agro-ecological practices
 - (a) High
 - (b) Low

Appendix 2: Questionnaire for examining *Ugunduzi* app

This study is being conducted to collect information of assessing level of acceptance and intention to continue using *Ugunduzi* app in agro-ecological researches in order to understand the potential of the app before promoting it to be used by majority. You have been using the app for about more than 2 years now. Hope you have gained experiences on its benefits and challenges. We therefore kindly request you to help us to complete this questionnaire as honestly as you can.

PART 1: RESPONDENTS' ATTRIBUTES

No.	Question	Response
1.	District Respondent come from	1. Morogoro 2. Masasi 3. Bagamoyo
2.	Name	
3.	Sex of respondent	1. Male 2. Female
4.	Age of respondent	
5.	Education	1. Primary 2. Secondary 3. College
6.	Experience on using smartphone	1. Used 2. Not used (before ugunduzi)

PART 2: RESPONSE ON THE AGREEMENT ON USING *UGUNDUZI* APP

Below are several aspect of farmers' experiences on using *ugunduzi* app. kindly please as honestly as you can rate your level of agreement or disagreement by ticking one answer for each item using by the following scale:

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
SD	D	N	A	SA

No	Code	Constructs and their items	Response				
			SD	D	N	A	SA
1.	PU	Perceived Usefulness					
	PU1	<i>Ugunduzi</i> app eases my research farming tasks	1	2	3	4	5
	PU2	<i>Ugunduzi</i> app supports critical aspects of my research farming activities	1	2	3	4	5
	PU3	Using <i>Ugunduzi</i> app saves my time in performing research farming activities	1	2	3	4	5
	PU4	<i>Ugunduzi</i> app improves quality of my research farming activities	1	2	3	4	5
	PU5	<i>Ugunduzi</i> app improves performance of my research farming activities	1	2	3	4	5
	PU6	<i>Ugunduzi</i> app supports my farming productivity improvement	1	2	3	4	5
	GPU	<i>Ugunduzi</i> app is useful to support agro-ecological research farming	1	2	3	4	5
2.	PE	Perceived Ease of use					
	PE1	<i>Ugunduzi</i> app provides helpful guidance	1	2	3	4	5
	PE2	It is easy to recover from errors while using <i>ugunduzi</i> app	1	2	3	4	5
	PE3	Using <i>Ugunduzi</i> app does not require a lot of mental efforts	1	2	3	4	5
	PE4	It is easy to learn and understand <i>Ugunduzi</i> app	1	2	3	4	5
	PE5	User manual is not much required when using <i>Ugunduzi</i> app	1	2	3	4	5
	PE6	<i>Ugunduzi</i> app is flexible and non-rigid to interaction with	1	2	3	4	5
	GPE	<i>Ugunduzi</i> app is easy to use in supporting agro-ecological farming research					
3.	US	User Satisfaction					
	US	I am satisfied that <i>Ugunduzi</i> app is a more appropriate technology to support agro ecological research farming	1	2	3	4	5
4.	CI	Continuance Intention					
	CI1	I intend to continue using <i>Ugunduzi</i> app in the future.	1	2	3	4	5
	CI2	Other fellow farmers are urged to use <i>Ugunduzi</i> app	1	2	3	4	5
	CI3	I appreciate <i>ugunduzi</i> app as the best technology to be used in agro-ecological farming	1	2	3	4	5

Appendix 3: Questionnaire for field visit

1. Name of the respondent
2. District respondent come from
3. What is the size of your research farm for this farming season
4. How many experiment plots for this year
5. Have you applied cow dung manure for soil management this year?
6. If yes at what volume
7. Have you applied poultry manure for soil management this year?
8. If yes at what volume
9. What have you gotten (Yield) in kg in
 - a. Control plot
 - b. Cow dung manure
 - c. Poultry manure
10. What is your view concerning research

Appendix 4: *Ugunduzi* app user manual



Ugunduzi: research and record keeping



Login screen:
On the login screen, enter your name and password and press the 'Start' button.



The menu is always here!

Your farm:
This is how your farm will look like after you have finished drawing it.
See the other side of this page for instructions on how to manage your records.



Draw farm:
To create your farm, first you will need to enter its name and its total size in acres. When finished, press 'OK'.



In the farm, you can draw up to 16 plots. Press the central part of a plot to move it, and release it when it reaches the desired position.

Press this button and move your finger to resize the plot, and release it when it has reached the desired size.

Press this button to define the crops and treatments in the plot.



You can add more plots to your farm by choosing the option 'Add plot' from the menu. In the menu, you will also find these options:

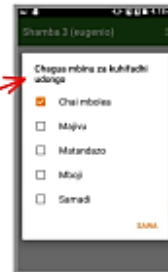
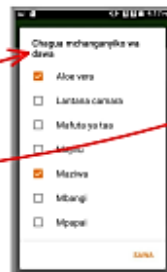
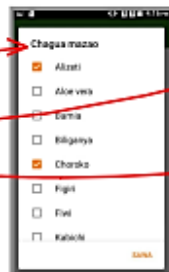
- Delete selected plot
- Edit farm name and size
- Cancel new or edited farm

When you are finished drawing your farm, choose the option 'Save farm'.

Define plot contents:

Select the crops and treatment ingredients of the selected plot by pressing the corresponding button

Choose the crops and treatment ingredients (if any) of the selected plot. Scroll through the list and select as many crops or treatment ingredients as you want. When finished, press 'OK'.



Appendix 5: Research permit to conduct research at Coast Region

CLEARANCE PERMIT FOR CONDUCTING RESEARCH IN TANZANIA



SOKOINE UNIVERSITY OF AGRICULTURE
OFFICE OF THE VICE-CHANCELLOR
 P.O. Box 3000 CHUO KIKUU, MOROGORO, TANZANIA
 Phone: 255-023-2640006/7/8/9, Direct VC: 2640015; Fax:
 2640021;
 Email: vc@suanet.ac.tz;

Our Ref. SUA/ADM/R.1/8/379

Date: 4th April, 2019

The Regional Administrative Secretary,
 Coast Region,
COAST.

Re: UNIVERSITY STAFF, STUDENTS AND RESEARCHERS CLEARANCE

The Sokoine University of Agriculture was established by University Act No. 7 of 2005 and SUA Charter, 2007 which became operational on 1st January 2007 repealing Act No. 6 of 1984. One of the mission objectives of the university is to generate and apply knowledge through research. For this reason the staff and researchers undertake research activities from time to time.

To facilitate the research function, the Vice Chancellor of the Sokoine University of Agriculture (SUA) is empowered to issue research clearance to staff, students, research associate and researchers of SUA on behalf of the Tanzania Commission for Science and Technology.

The purpose of this letter is to introduce to you **Ms. Luambano Kihoma** a bonafide **PhD (Agricultural Education and Extension)** student with registration number **PEE/D/2018/0001** of SUA. By this letter **Ms. Luambano Kihoma** has been granted clearance to conduct research in the country. The title of the research in question is "**Validation of Ugunduzi App in enhancing Smallholder Farmer's Crop Productivity through Farmer-led Research of Agro-ecological Practices in Tanzania**".

The period for which this permission has been granted is from **April, 2019** to **April, 2021**. The research will be conducted in **Coast Region**.

Should some of these areas/institutions/offices be restricted, you are requested to kindly advice the researcher(s) on alternative areas/institutions/offices which could be visited. In case you may require further information on the researcher please contact me.

We thank you in advance for your cooperation and facilitation of this research activity.

Yours sincerely,

Prof. P.R. Gillah
FOR: VICE-CHANCELLOR

Copy to: Student – **Ms. Luambano Kihoma**

VICE CHANCELLOR
 SOKOINE UNIVERSITY OF AGRICULTURE
 P. O. Box 3000
 MOROGORO, TANZANIA

Appendix 6: Research permit to conduct research at Mtwara Region**CLEARANCE PERMIT FOR CONDUCTING RESEARCH IN TANZANIA**

SOKOINE UNIVERSITY OF AGRICULTURE
OFFICE OF THE VICE-CHANCELLOR
 P.O. Box 3000 CHUO KIKUU, MOROGORO, TANZANIA
 Phone: 255-023-2640006/7/8/9, Direct VC: 2640015; Fax:
 2640021;
 Email: vc@suanet.ac.tz;

Our Ref. SUA/ADM/R.1/8/380

Date: 4th April, 2019

The Regional Administrative Secretary
 Mtwara Region,
 MTWARA.

Re: UNIVERSITY STAFF, STUDENTS AND RESEARCHERS CLEARANCE

The Sokoine University of Agriculture was established by University Act No. 7 of 2005 and SUA Charter, 2007 which became operational on 1st January 2007 repealing Act No. 6 of 1984. One of the mission objectives of the university is to generate and apply knowledge through research. For this reason the staff and researchers undertake research activities from time to time.

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The purpose of this letter is to introduce to you **Ms. Luambano Kihoma** a bonafide **PhD (Agricultural Education and Extension)** student with registration number **PEE/D/2018/0001** of SUA. By this letter **Ms. Luambano Kihoma** has been granted clearance to conduct research in the country. The title of the research in question is "**Validation of Ugunduzi App in enhancing Smallholder Farmer's Crop Productivity through Farmer-led Research of Agro-ecological Practices in Tanzania**".

The period for which this permission has been granted is from **April, 2019 to April, 2021**. The research will be conducted in **Mtwara Region**.

Should some of these areas/institutions/offices be restricted, you are requested to kindly advise the researcher(s) on alternative areas/institutions/offices which could be visited. In case you may require further information on the researcher please contact me.

We thank you in advance for your cooperation and facilitation of this research activity.

Yours sincerely,

Prof. P.R. Gillah
FOR: VICE-CHANCELLOR

Copy to: Student – **Ms. Luambano Kihoma**

VICE CHANCELLOR
 SOKOINE UNIVERSITY OF AGRICULTURE
 P. O. BOX 3000
 MOROGORO, TANZANIA

Appendix 7: Research permit to conduct research at Morogoro Region

CLEARANCE PERMIT FOR CONDUCTING RESEARCH IN TANZANIA



**SOKOINE UNIVERSITY OF AGRICULTURE
OFFICE OF THE VICE-CHANCELLOR**

P.O. Box 3000 CHUO KIKUU, MOROGORO, TANZANIA
Phone: 255-023-2640006/7/8/9, Direct VC: 2640015; Fax:
2640021;
Email: vc@suanet.ac.tz;

Our Ref. SUA/ADM/R.1/8/378

Date: 4th April, 2019

The Regional Administrative Secretary,
Morogoro Region,
P.O. Box 650,
MOROGORO.

Re: UNIVERSITY STAFF, STUDENTS AND RESEARCHERS CLEARANCE

The Sokoine University of Agriculture was established by University Act No. 7 of 2005 and SUA Charter, 2007 which became operational on 1st January 2007 repealing Act No. 6 of 1984. One of the mission objectives of the university is to generate and apply knowledge through research. For this reason the staff and researchers undertake research activities from time to time.

To facilitate the research function, the Vice Chancellor of the Sokoine University of Agriculture (SUA) is empowered to issue research clearance to staff, students, research associate and researchers of SUA on behalf of the Tanzania Commission for Science and Technology.

The purpose of this letter is to introduce to you **Ms. Luambano Kihoma** a bonafide **PhD (Agricultural Education and Extension)** student with registration number **PEE/D/2018/0001** of SUA. By this letter **Ms. Luambano Kihoma** has been granted clearance to conduct research in the country. The title of the research in question is "**Validation of Ugunduzi App in enhancing Smallholder Farmer's Crop Productivity through Farmer-led Research of Agro-ecological Practices in Tanzania**".

The period for which this permission has been granted is from **April, 2019** to **April, 2021**. The research will be conducted in **Morogoro Region**.

Should some of these areas/institutions/offices be restricted, you are requested to kindly advice the researcher(s) on alternative areas/institutions/offices which could be visited. In case you may require further information on the researcher please contact me.

We thank you in advance for your cooperation and facilitation of this research activity.

Yours sincerely,

Prof. P.R. Gillah

FOR: VICE-CHANCELLOR

Copy to: Student – **Ms. Luambano Kihoma**

VICE CHANCELLOR
SOKOINE UNIVERSITY OF AGRICULTURE,
P. O. Box 3000
MOROGORO, TANZANIA