MOBILE-BASED PEER-TO-PEER LEARNING PROTOTYPE FOR SMALLHOLDER DAIRY PRODUCERS

Fatuma Mavura

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master's in Information Systems and Network Security of the Nelson Mandela African Institution of Science and Technology

Arusha, Tanzania

June, 2023

ABSTRACT

About half of Africa's animal production comes from smallholder dairy farmers, who employ various strategies to maximize milk output. Some time-consuming and expensive heuristics are used by smallholder dairy farmers to increase milk yield, trapping them in a cycle of failure and lowering their incentive to continue making agricultural investments. Grouping smallholder dairy producers with comparable characteristics makes information sharing and interventions easier, increasing milk output. This study aimed at developing a mobile-based peer-to-peer learning prototype which considers farmers' homogeneity with respect to husbandry practices and auto-allocates them to their respective production clusters. The developed prototype's rule-based engine handles the auto-allocation procedure by grouping farmers with similar farming characteristics into the proper production clusters. Smallholder dairy producers exchange knowledge and expertise through these groups to increase milk output. In Tanzania's Arusha Region, 69 smallholder dairy farmers and nine extension workers responded to a questionnaire to provide information, which was then analyzed using R programming. The important findings are; smallholder dairy producers were automatically allocated to their clusters based on their milk output. Cluster position regarding milk yields was determined using cluster performance for overall production attributes. Consequently, high-yielding smallholder dairy producers are assigned to the high-yielding cluster, and vice versa, and extension officers provide timely support. This study is unique since smallholder dairy producers may use it to share dairy farming expertise and boost milk output. Mobile-based peer-to-peer should be integrated with the market by engaging enterprises that process milk for other milk products.

DECLARATION

I, Fatuma Mavura, do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my original work and that it has neither been submitted nor is concurrently submitted for degree award in any other institution.

Fatuma Mavura		17.07.2023
Name of Candidate	**Signature**	**Date**

The above declaration is confirmed by:

Dr. Devotha G. Nyambo		**18.07.2023**
Name of Supervisor 1	**Signature**	**Date**

Dr. Elizabeth Mkoba		**17-07-2023**
Name of Supervisor 2	**Signature**	**Date**

CERTIFICATION

The undersigned certify that they have read and, with this recommendation for acceptance by the Nelson Mandela African Institution of Science and Technology, a dissertation titled ***"Mobile-Based Peer-to-Peer Learning Prototype for Smallholder Dairy Producers"*** in partial fulfilment of the requirements for the degree of the Master of Science in Information Systems and Network Security of the Nelson Mandela African Institution of Science and Technology.

Dr. Devotha G. Nyambo		**18.07.2023**
Name of Supervisor 1	**Signature**	**Date**

Dr. Elizabeth Mkoba		**17-07-2023**
Name of Supervisor 2	**Signature**	**Date**

ACKNOWLEDGMENTS

First of foremost would like to express my sincere gratitude to God Almighty for His kindness and guidance during my studies.

Second, I would like to acknowledge the Ministry of Education, Science and Technology (MoEST) for providing me with the scholarship that allowed me to further my education.

It is only right that I express my sincere gratitude to my supervisors, Dr. Devotha G. Nyambo, Dr. Elizabeth Mkoba, and Mr. Sanket Pandhare, for their invaluable advice, constant support, and patience throughout my Master's study experience. Their vast expertise and wealth of experience have aided me throughout my academic career and daily life.

I also appreciate all the Nelson Mandela African Institution of Science and Technology (NM-AIST) staff members who assisted me in some way. Their generous assistance and support have made my time at the NM-AIST a delightful experience.

Finally, I want to thank my parents and other family members for their support. In addition, I would like to thank the following people Mr. Eric Mbena, Mr. Paul Boniface, Mr. Emmanuel Patrick, Mr. Sadick Buhuru, Ms. Rosemary Panga, and all my friends. Completing my studies would be impossible without their tremendous support and encouragement.

DEDICATION

With deep thanks and heartfelt tribute, I dedicate this work to my parents, Mr. Mavura Msuya and Ms. Mwanaid Ramadhani, for their love and encouragement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AOS	Android Operating System
API	Application Programming Interface
CoCSE	School of Computational and Communication Science and Engineering
DFD	Data Flow Diagram
GDP	Gross Domestic Product
GUI	Graphical User Interface
ICT	Information and Communication Technology
IDE	Integrated Development Environment
ILRI	International Livestock Research Institute
MDC	Meru District Council
MoEST	Ministry of Education, Science and Technology
NAIC	National Artificial Insemination Center
NM-AIST	The Nelson Mandela African Institution of Science and Technology
OS	Operating System
SMS	Short Message Service
SSA	Sub-Sahara African
TAM	Technology Acceptance Model

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Dairy farming is an agricultural activity focused on milk production. Smallholder dairy farming schemes compose an essential source of subsistence for most farmers engaged in farming productivity (Atuhaire *et al.,* 2014) and catering to dairy demand. Smallholder dairy producers are challenged to achieve appropriate milk yields (Alonso *et al.,* 2014). The proper framework and substructure should be employed to guarantee farmers are supported with the required services, which may help maximise their production. Smallholder dairy farmers contribute about 50% of the entire livestock yeld in Africa in the pasturage venture (Lowder *et al.,* 2016; Swai *et al.,* 2014). East Africa is in the first position for milk production in Africa; it contributes about 68% of the milk produced in Africa (Bingi & Tondel, 2015). East African countries suffer similar problems, such as low dairy productivity and deficient milk quality. Tanzania's livestock productivity is low, as it is in other underdeveloped nations (Waziri & Uliwa, 2020). Tanzania's need for fresh milk is increasing, but native dairy practitioners cannot keep pace with the needs. The International Livestock Research Institute (ILRI) predicts a six hundred million litre milk shortfall in 2020 due to an estimated 4% annual GDP growth and a 5% annual rate of urbanization, posing a significant sector development problem (Brett, 2019).

Smallholder farmers make up most of Tanzania's dairy industry, which struggles for some reasons, including that 97% of the country's dairy cows are poor-producing breeds, and deprived administration techniques are common. There are periodic fluctuations in forage and feed accessibility. This prevents a lot of smallholder farmers from getting access to veterinarian or extension services at a reasonable price. Smallholder dairy producers are characterized by low herds size, small fields, and low commercial preference for household’s day-to-day substance (Lowder *et al.,* 2016; Swai *et al.,* 2014). Poor productivity and commercialization in dairy farming accompany its features like breeding technology, feeding techniques, and infrastructures (Guadu & Abebaw, 2016). The comprehensive contemporary survey reports some dairy producers to generate significantly more than the average (PEARL data, 2016). For increasing milk, yielding dairy farmer groups should be aided in using technology to enhance quality and quantity production (Kyaruzi *et al.,* 2019). Effective classification can help agricultural growth in SSA by informing extension services (Ahikiriza *et al.,* 2021). It is reported that the predominance of these smallholders deprived their production perspective regarding commercialization and yielding (Nyambo *et al.,* 2019). Based on Sub-Saharan Africa (SSA), the smallholder dairy producers have highly similar main features across regions nevertheless, features pertinent to the dairy farmer management practices call for disaggregation. Since efficient classification can educate extension services that support agricultural development, farm typologies can aid in generating context-specific improvement solutions. As such, establishing better dairy farming managing activities and livestock support provisions can be successful if particular restraints are recognized per farm classification (Nyambo *et al.,* 2019). Due to the pertinent characteristics of farmers based on management practices, there are heterogeneous groups that intricate service delivery, knowledge sharing, and technology dissemination, predominantly for individuals who intend to maximize productivity and profitability. When smallholder farmers collaborate, they gain new skills and improve their ability to solve problems as a team. For the farmer to obtain desirable outcomes, they have to involve in cooperative collectiveness (Mudiwa, 2017).

For obtaining homogenous groups for easing intervention, it is indispensable to determine farmers' clusters who engage in akin managerial activities and have similar characteristics (Nyambo *et al.,* 2019). It is easier to learn about the growth of smallholder dairy producers when they are in a homogenous group. Through these groups' farmers can share information about exact restraining causes in numerous farm kinds (Goswami *et al.,* 2014). Peer-to-peer knowledge sharing between farmers bridges the gap between farmers and extension officers (Thakur & Chander, 2018). From previous research, farmers' production systems were defined and agent-based models simulated peer-to-peer learning (Nyambo *et al.,* 2020). Thus, this study aims to develop a mobile-based peer-to-peer learning prototype to leverage smallholderdiary producers' knowledge and complement extension support for increased milk yield.

1.2 Statement of the Problem

Smallholder dairy producers have tried several strategies to improve milk yielding, but these attempts involve several heuristics, time-consuming, and financial investments (Nyambo *et al.,* 2019). Agricultural extension and consulting services are key players in farming growth, poverty mitigation, and food security (Ahikiriza *et al.,* 2021). By advancing their technical knowledge, farm administration expertise, and information structure, farming extension and advice-giving facilities can assist farmers in identifying production and administration matters, which boosts productivity, higher returns on investment, and the growth of the national and global economies. On the other hand, extension services and delivery strategies frequently fail to satisfy farmers' needs and address technological obstacles. With insufficient and unavailable extension services (all farming support from extension workers such as feeding techniques, health services, etc.), farmers are stuck in failure loops and ineffective endeavours, which cause a decreased wish to carry on with farming speculation (Nyambo *et al.*, 2019). The significance of community-based intercommunication for farmer knowledge interchange among peers within farmer groups has been emphasized in numerous studies (Faysse *et al.,* 2012). However, the lack of mobile-based peer-peer learning tools that promote knowledge sharing between smallholder dairy producers in Tanzania was not implemented. Mobile-based peer-to-peer learning is an outstanding solution for sharing, replicating, and scaling up the improvement in dairy development.

Moreover, inspiring flexibility in individual learning behavior is more significant, intensifying the dissemination of achievements (Thakur & Chander, 2018). The ideal answer to the aforementioned issue is the mobile-based peer-to-peer learning prototype, which automatically allocates or groups smallholder dairy farmers with comparable features to their suitable production cluster. It automatically transfers any small-scale dairy producers who qualify to another cluster after 30 days. In agriculture, the importance of knowledge sharing between farmers and disseminating the most successful farming methods inspire other dairy practitioners to adopt the method to improve milk yield. Improving smallholder dairy producers' skills and knowledge, including new technology and practices, can seriously increase smallholder dairy producers' level of productivity (Patii *et al.*, 2017). Based on a previous study on the simulation of farmers' peer-to-peer learning, output revealed thatfarmer's interaction improves yielding from the actual average of 12.7 ± 64.89 to average milkyields in a simulated environment of 17.57 ± 60.72 in Tanzania (Nyambo, 2020) according todairy household's datasets collected under the PEARL project.

Although the simulations indicated significant improvement, farmers cannot use such simulated solutions. Consequently, aspirations are to make such a solution accessible and usable by dairy farmers through their handheld devices. Therefore, this research developed a mobile-based peer-to-peer learning prototype that enables smallholder dairy producers to share farming experiences and learn from each other to improve milk output.

1.3 Rationale of the Study

Most smallholder dairy producers are deprived of their production perspective regarding commercialization and yielding, given an inadequacy of awareness of the farmers on the production system they are working in (Nyambo *et al.,* 2019). Smallholder dairy producers' low productivity and commercialization are associated with its features, such as breeding technology, feeding techniques, and infrastructures (Guadu & Abebaw, 2016). Studying the growth of smallholder dairying in homogenous groups is simplified since farms with the same characteristics can share information about exact restraining causes in numerous farm kinds (Goswami *et al.,* 2014).

Research to obtain homogenous groups for easing intervention where farmers' clusters undertaking similar managerial activities and having similar characteristics were well defined and simulated in the agent-based models. The agent-based models help us abstract the scenarios, but smallholder dairy producers cannot use them. Therefore, there is a need to transform such model implementations into user-friendly and farmer-centred real-time tools where smallholder dairy producers can share knowledge regarding farming techniques to increase milk yield, and farmers can interact with extension officers (Nyambo *et al.,* 2019). Based on a previous study on the simulation of farmers' peer-to-peer learning, which has proven the positive results on milk yielding through knowledge sharing among peers (Nyambo, 2020), the proposed mobile-based peer-to-peer learning prototype development is too realistic. Through this study, extension workers would be obtained through reliance on individual farmers' knowledge, learning, and sharing experience in a peer-to-peer learning platform and some extension workers who should be in the system.

1.4 Research Objectives

1.4.1 General Objective

To develop a mobile-based peer-to-peer learning prototype to boost milk output for smallholder dairy farmers.

1.4.2 Specific Objectives

(i) To identify requirements for dairy producers' profiling and assignment into pre-existing production clusters.

(ii) To develop a mobile-based peer-to-peer learning prototype for smallholder dairy producers.

(iii) To validate the developed prototype.

1.5 Research Questions

(i) Which procedures are employed to group smallholder dairy producers with certain traits into the appropriate cluster?

(ii) How was the prototype for smallholder dairy producers' mobile-based peer-to-peer learning developed?

(iii) How can the created prototype be validated?

1.6 Significance of the Study

This study developed a user-friendly peer-to-peer learning prototype for mobile devices that smallholder dairy farmers can use to share skills and professionalism concerning dairy farming, aiming to boost milk output. Clustering is a mobile-based peer-to-peer system that groups smallholder dairy farmers with similar farming characteristics (clusters). Furthermore, as the name suggests, the developed solution allows these farmers to learn from one another in their clusters through conversing. Moreover, smallholder dairy producers can assess themselves daily regarding milk yield, making tracking their dairy farming performance easier. Farmers can also communicate to extension officials in the developed peer-to-peer learning prototype for any farming-related assistance, with the primary objective of raising milk production.

1.7 Delineation of the Study

The study presupposed that every smallholder dairy producer has a smartphone. Therefore, in this study, the milk peak value was used as a rules engine to automatically place farmers in the right clusters among the 10 production parameters that were chosen.

Despite its success, the built peer-to-peer learning prototype has some limitations, including the inability to recommend or suggest the cluster's top performer (a smallholder dairy producer) after every 30 days. Furthermore, the developed prototype lacks a recommender system that can offer smallholder dairy farmers the best practices or solutions, which, if followed, will enable them to increase milk production.

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical Literature Review

2.1.1 Social Constructivism Theory

Social constructivism theory is also identified as a collaborative learning theory suggested by Lev Vygotsky in 1968. Learning is a social activity where one connects with other human beings, like peers, to gain knowledge as they share different experiences (Akpan & Okoro, 2020). This theory teaches that social interaction and language use is where all knowledge develops, rather than an individual experience. Moreover, social negotiation knowledge develops through social negotiation and assessment of feasible individual understanding. Conversations between two or more people allow you to learn something new or improve on something you already know (Lynch, 2016).

Vygotsky believes that since life is a protracted development process, social connection is essential because social learning leads to cognitive development. The social constructivism theory was adopted in this study because knowledge sharing between peers (smallholder dairy producers) can be performed under the guidance of the extension officers. The theory gives backup to initiating opportunities for collaboration between smallholder dairy producers for knowledge sharing and understanding. Interacting with people, the material and immaterial environment, understanding is obtained and gathering experience (Akpan & Okoro, 2020). This study adopted the social constructivism theory because it supports the idea that social learning leads to cognitive development. As part of this study, smallholder dairy farmers exchange knowledge and expertise with their colleagues to boost milk production.

2.1.2 Social Learning Theory

Alberta Bandura coined the social learning theory in 1971. It is a theory of the learning process and social behavior, which proposes that new behaviors are learnt by watching and imitating fellows. According to Tran (2013), in social learning theory, learning occurs in a community-based environment where learners obtain knowledge, rules, skills, strategies, beliefs, and by observing others.

The social learning theory proposes that social performance is learned by observing and imitating the performance of others (Rumjaun & Narod, 2020). The theory was adopted because it describes how people learn new ideas by watching and imitating others. For example, smallholder dairy farmers might study the farming techniques used by their peers in their clusters to boost milk yield.

2.1.3 Unified Theory Acceptance and Use of Technology

The fast growth and widespread adoption of information technology in all spheres of society, including the social economy, industrial process, and consumption structure, has resulted in significant changes (Wang *et al.,* 2022). Only until information technology is embraced, used, and consistently used can its value as a productivity development tool be revealed. These theories treat one's usage intention or behavior as a dependent variable and one's perception of how useful technology can be as an independent variable.

Researchers explain how internal ideas, attitudes, and other variables influence people's acceptance of information technology. This study adopted the Unified Theory Acceptance and Use of Technology theory to evaluate the acceptance and use of the peer-to-peer learning prototype. Utilizing and adopting any technology is a significant barrier to reaping benefits (Venkatesh, 2022). According to this study, deploying and adopting the developed solution technology increase milk output.

2.1.4 Technology Acceptance Model

Davis (1986) proposed the Technology Acceptance Model (TAM), including perceived utility, perceived ease of use, attitude, and the existing system. Lai (2017) and Davis *et al.* (1989) developed a modified version of TAM that includes perceived usefulness, perceived ease of use, attitude, behavior intention, and actual usage. TAM was adapted from Ajzen's (1985) theories of Reasoned Action and the Theory of Planned Behavior. According to Venkatesh *et al.* (2012), external factors significantly impact internal elements, including beliefs and trust, attitudes, and intentions to utilize products or services.

In most research, validation in testing a model's adoption behavior was high, indicating that the TAM model placed a greater emphasis on the psychological characteristics of an individual, indicating the importance of perceived usefulness and ease of use of various technology adoptions. Furthermore, the model has been enhanced with numerous factors and dimensions, such as the development of TAM2, TAM3, and numerous additional technology adoption characteristics.

Based on the above theories, TAM was also adopted in this study for the users' acceptance test (i.e., validation of the proposed system).

2.2 Empirical Literature Review

Digital technologies have an outstanding perspective on helping farmers acquire and access information for agricultural enhancement and livestock production. For instance, cell phone usage has a huge potential to enhance productivity for smallholder farmers (Sennuga *et al.,* 2020; Velmurugan *et al.,* 2016). Furthermore, Information and Communication Technology (ICT) is considered a tool and provenance of information and mastery to extension workers to reach a broader audience (Sennuga *et al.,* 2020).

Mobile phone use is the greatest universal means of information distribution lane (Atuhaire *et al.,* 2014). One of the most important functions of mobile technology is to make information easily accessible, shareable, and available where it was previously difficult to generate and transmit (Thiam & Matofari, 2018). Mobile phone value in service delivery to farmers has attained much attention since it helps them disseminate information; they can receive information about farming issues through their phones (Baumüller, 2018). Mobile phones' expeditious spread worldwide provides chances to get to frequently distant, distributed, and poorly serviced farmers by overcoming obstruction of space and social status. Information and Communication Technology has an additional dimension to communication as it connects farmers, allowing them to access extension facilities, and helps raise consciousness. Furthermore, farmers acknowledge using the mobile phone as easy, fast, and appropriate communication.

Mobile phone technology utilization among farming groups enhances the standard and pace of the distribution of extension facilities (Marwa *et al.,* 2020). The information-dissemination procedure alongside the dairy value chain is mainly electronic media, mostly mobile phones. The most solicited types of information by dairy performers (all people involved in the dairy activity) are feeds and health services (Thiam & Matofari, 2018). Several countries are using mobile phone technology to improve their farming systems as it gives pastoral farmers the opportunity to use particular information in farming technology (Ng'ang'a, 2013).

India, Nigeria, and Uganda are countries where cell phone use has enhanced agricultural output. The mobile SMS (Short Message Services) record system was established in Malawi for quality and reliable information. Moreover, ease the information sharing between smallholder dairy farmers and other value chain participants where farmers can link with appropriate extension officers to improve production in dairy farming (Chiumia *et al.,* 2020). This study successfully allowed smallholder dairy producers to acquire dairy information from extension workers; however, this SMS-based approach did not group farmers with comparable farming characteristics for easy intervention and farm management support. Furthermore, Taneja *et al.* (2019) researched the examination of animal behavior and health tracking and the provision of effective awareness to improve farming practices using the Internet of Things (IoT) platform, thus escalating effectiveness and yielding.

Moreover, information and knowledge transfer in agriculture are more important; lacking them can hinder farming productivity in pastoral communities in sub-Saharan Africa (SSA). Mobile phones are standing with a transformative perspective of reaching many farmers simultaneously across pastoral locations. Farmers can also disseminate information regarding their farming activities with the help of mobile phone services (Krell *et al.,* 2020). Research done by Marwa (2019) showed that the iCow mobile platform that uses SMS to facilitate information sharing between smallholder dairy producers and the experts. The study found that this application has bridged the gap between the researchers' experts and practitioners by bringing verified agricultural research to the farmer so that a farmer can understand and act (Marwa *et al.,* 2020). This research also did the best job of connecting smallholder dairy farmers with experts so that farmers receive advice from experts regarding farming issues via SMS that they can act upon. However, the application does not provide a space for farmers to share knowledge among themselves, and they cannot send the SMS to experts to ask for support in case they encounter any difficulties on their farms.

The study by Makau *et al.* (2018) argues that smallholder dairy producers in Kenya recognize an important constructive inference amongst improved milk yields and the provision of cell phone extension services. Consequently, knowledge of the utilization of information and communication technology should upsurge farmers to improve farming productivity and increase income in smallholder dairy producers’ production initiatives. However, the ability to use mobile phones advances to deliver specialized agricultural information and services to enhance the productivity of smallholder farmers in Sub-Saharan Africa (SSA) is still mostly unrealized (Omulo & Kumeh, 2020). Information and Communication Technology (ICT) services are becoming more prevalent and widely used to provide agricultural information to small-scale farmers and extension workers. This study facilitated knowledge sharing among smallholder dairy farmers about farming issues among them and with extension officers. However, it was unsuccessful in clustering farmers with similar characteristics for knowledge sharing and also for straightforward intervention with extension officers.

Generally, these studies have focused on ensuring farmers get information through their mobile phones through short messages regarding farming issues. However, the previous studies have not implemented the cluster-based solution through which smallholder dairy producers with similar characteristics are clustered into their belonging clusters. Furthermore, a rule-based engine in the prototype automatically places farmers in the proper clusters.

Additionally, prior studies have not tapped into farmers' knowledge to augment extension support because present solutions are centralized. The suggested solution is a decentralized learning strategy where authorized extension officers should offer all assistance to smallholder dairy farmers addressing farming difficulties to increase milk yield. Smallholder dairy farmers should also exchange knowledge and expertise about farming to increase milk production.

2.3 Conceptual Framework

The term "conceptual framework" is employed in research methods (Varpio *et al.,* 2020); they give an overview of the study's structure (Crawford, 2020). The conceptual framework for the peer-to-peer learning prototype for mobile devices is shown in Figure 1, along with the various stages of use for the prototype by smallholder dairy producers. Smallholder dairy farmers must provide user names, email addresses, phone numbers, and home addresses during the user registration step, which is the first stage. After a smallholder dairy producer has completed enrollment, the rule-based engine determines specific qualities of the farmer and automatically assigns them to their relevant group. Viewing the farming rules of a certain production cluster is the third stage. Finally, smallholder dairy producers check over the production cluster's guidelines and compare them to their farming standards to see whether they match and if there are any discrepancies, they may use to boost milk output.

The fourth stage is to adopt farming rules; smallholder dairy producers establish farming rules specific to their productionss cluster to boost milk yields. The fifth stage is self-evaluation, which occurs after accepting the farming guidelines and involves smallholder dairy producers looking at the graph on their dashboards to assess their progress. Finally, the developed prototype measured milk yield after a month to determine average production. Finally, the rule-based engine determines whether the farmer is suitable for placement in another production cluster and then moves them to the right cluster.

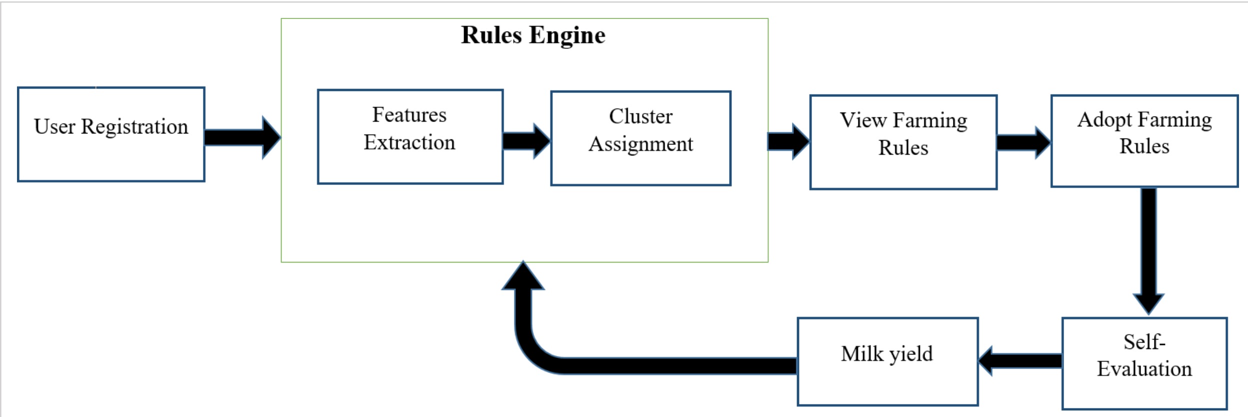


Figure 1: Conceptual framework

CHAPTER THREE

MATERIALS AND METHODS

3.1 Area of the Study

The study was carried out in the Arusha region (Meru District) because the Arusha region is among the top five best performers in milk production in Tanzania. Furthermore, the Arusha region is among the leading smallholder dairy farming regions. In addition, only three districts (Meru, Arusha City, and Arusha district) practice crossbreeding technology compared to other regions in the top five, such as Kilimanjaro, Tanga, Dar-Es-salaam, and Mbeya. The second reason is that the National Artificial Insemination Center (NAIC) is located in Meru District (Usa-river area) in Arusha, where more dairy farming experts are in number over other regions in Tanzania. Moreover, NAIC is the main distributor of services to its sub-branch in a particular area, for example, the NAIC branch in the Pwani region (Kibaha District) (NAIC report, 2021 unpublished).

Meru District Council is one of the seven councils comprising the Arusha Region. It is located 5 km east of Arusha town in northeastern Tanzania, and roughly, it occupies around 50 km^2 on the southeastern slopes of Mount Meru. This extinct volcano rises 4565 m above sea level. On the slopes of Mount Meru, Meru District Council is between Latitude 3'000 – 360 and Longitude 080 – 520 in the Eastern South of the Equator. The study was conducted within three wards, namely Kikwe (3.4287° S, 36.8308° E), Sing’isi (3.3732° S, 36.8062°) E and Akheri (3.3734° S, 36.7815° E) in Meru District, in Arusha region Tanzania as shown in Fig. 2.

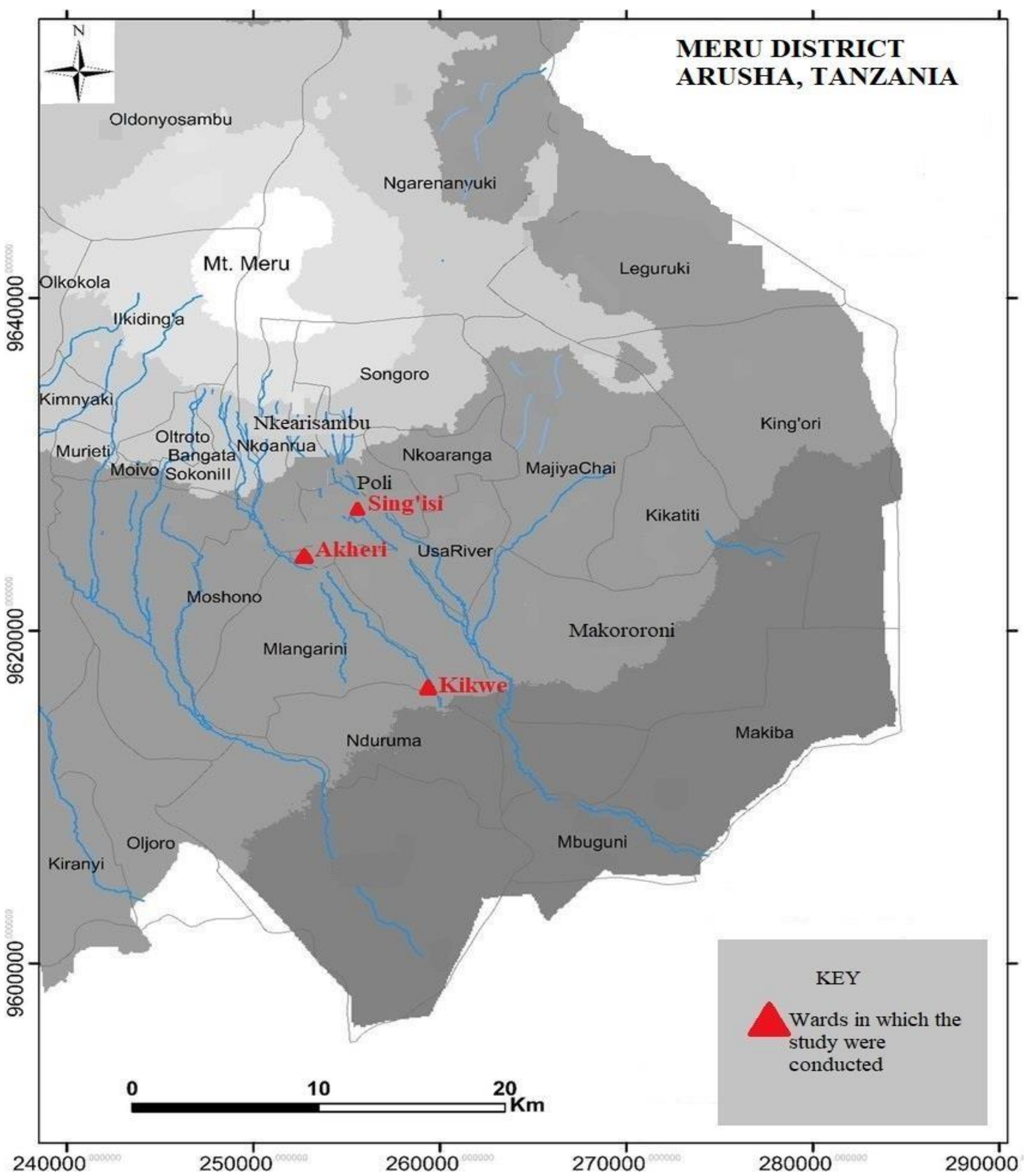


Figure 2: A map of Meru District showing Wards where the study was conducted

3.2 Research Design

There are various research designs, such as descriptive, exploratory, and causal studies. A descriptive study is in the form of a longitudinal and cross-sectional study. Cross-sectional descriptive research is one in which data on the existence or level of one or more variables of interest is collected without respect to any causal or other hypotheses. The research design adopted in this study was a descriptive cross-sectional study design because it allows the simultaneous comparison of many different variables. Furthermore, the descriptive cross-sectional study design is applied mostly in quantitative research.

3.3 Research Methods

Qualitative, quantitative, and mixed-method research approaches have been used in research. Qualitative research tries to get a comprehensive understanding of the phenomenon under study. On the other hand, the quantitative research method is concerned with quantifying notions that yield numerical values for statistical computation. Finally, in the mixed method, both qualitative and quantitative methods are used in the research.

Therefore, this study adopted a quantitative research method, and the questionnaire was used for data collection. The data collected were analyzed using the statistical analysis method to find each production feature's minimum value, maximum value, and mean value for each cluster, aiming to get the best-performing, best-performing, poor-performing, and following poor-performing clusters. The statistical analysis helped allocate smallholder farmers to their belonging cluster based on the production performance.

3.4 Target Population and Sample Size

3.4.1 Target Population

The target population is the whole or group population in which a researcher is fascinated to investigate and arrive at a conclusion. The target population of this study is the smallholder dairy producers who keep cross-breed or exotic cattle together with extension officers who will use the developed peer-to-peer learning prototype. The main goal of this study was to develop a mobile-based peer-to-peer learning prototype for smallholder dairy producers. Farmers should be allocated to their unique production groups to share information and expertise about dairy husbandry and increase milk yield.

3.4.2 Sample Size

In a survey or investigation, the sample size is a portion of the population chosen. It is the number of participants or observations included in a study and represented by n.

The sample size for the infinity population is given by:

$$\frac{S=(z)2*p*(1-p)}{(M)2} \tag{i}$$

Where:

S represents the sample size of the infinity population

z represents the z-score

M represents the Margin of error

The sample size for the required population is given by

$$n = \frac{S}{1+\left(\frac{S+1}{N}\right)} \qquad \text{(ii)}$$

Where:

n represent the sample size of the required population

S represent the sample size of the infinity population

N represent the population size

The 3500 smallholder dairy farmers were taken from the study by Nyambo *et al.* (2019), where they highlighted the ten production criteria employed in this work to create a peer-to-peer learning prototype that automatically clusters farmers with like traits in their production clusters. The study's sample size was 78 people, of whom 69 were small-scale dairy farmers, and 9 were extension agents. Formulas (i) and (ii) were used to determine the sample size. The margin of error is 8.6% when the confidence level (z) is 85%. The distribution of sample sizes is depicted in Table 1.

Table 1: Sample size distribution (Filed data, 2021)

Category of sample	Sample size
Smallholder dairy producers	69
Extension Officers	9
Total	78

3.5 Sampling Procedures

There are various sampling techniques, such as simple random sampling, systematic sampling, stratified sampling, clustered sampling, convenience sampling, quota sampling, judgment (or purposive) sampling, and snowball sampling. Simple random sampling and selective sampling methods were employed in this research. The extension officers were chosen using the purposive sample approach because they thoroughly understand dairy farming. The selection strategy in purposive sampling relies on the researcher's estimation of which individuals will be most helpful in achieving the study's objectives. Furthermore, smallholder dairy producers in Meru District were selected using simple random selection. A sampling technique is known as "choosing at random" guarantees that each object in the universe has a fair opportunity to get chosen for the sample. This is to say that each smallholder dairy producer had an equal chance to be selected as a sample.

3.6 Data Collection Methods

In this research, primary and secondary data sources were employed in the data capture process. The sections that follow address these techniques.

3.6.1 Primary Data Collection

Primary data from dairy farmers and extension agents were gathered using standardized survey questionnaires. As seen in Appendix 1, the survey initially targeted small-scale dairy farmers. This survey was designed to obtain data on the practices and processes that could boost the milk production of smallholder dairy producers. The second questionnaire, as shown in Appendix 2, was for extension officers. This survey intends to answer questions about production factors that, if implemented by smallholder dairy producers, can help them enhance milk yield.

3.6.2 Secondary Data Collection

The secondary data was collected from various journals, books, government reports from the Ministry of Livestock and Fisheries (MLF) of Tanzania and research reports from several websites. Three thousand five hundred dairy farmers in Tanzania were chosen from the preceding study by Nyambo *et al.* (2019), with six clusters and seven proposed production features. These characteristics include milk peak value, number of milking cows, total land, extension visits, and vaccination and watering frequency. The last three production traits, feed type, feeding frequency, and milking frequency, are extrapolated from first-hand field information. Finally, the seven chosen features and the three field-gathered features were combined to form the 10 production features used in this study.

3.7 Data Analysis

The data analysis is presented in three phases: data preparation, coding, and analysis, as explained in the following sections.

3.7.1 Data Preparation

First, dairy farmers and Meru District Council extension agents' information was gathered throughout the data preparation phase. Data preparation is cleaning and altering raw data before processing and analysis. It's a vital and necessary step before processing to place data in context so that it may be turned into insights and biases caused by poor data quality can be reduced. Given that the study was quantitative, the collected data (raw data) was transformed into numerical values for analysis. After data collection, data discovery and assessment took place where the 10 production features that improve milk yielding were selected. Seven production features had been adapted from the prior work by Nyambo *et al.* (2029), and the remaining three were from the primary data gathered from the field.

3.7.2 Data Coding and Cleaning

The data from sub-section 3.6.1 that was uncovered was cleaned by eliminating invalid data and completing any gaps. This includes eliminating redundant data and erroneous filling in blanks, reshaping data to suit a certain trend, and hiding important or confidential entries. For data cleaning, the Microsoft Excel filter was used, and for data coding, certain formulas were used to assign assimilated values to that data. This means that the formulas for associating the assigned numbers with the original data (word row data) were introduced after row data transformation from words to numbers.

3.7.3 Data Analysis

R Programming Tool was used to process primary data after importing the required data into the R working environment. First, the code was written to obtain the minimum values, maximum values, and mean values of the 10 production features (vaccination frequency, watering frequency, milking frequency, feeding frequency, feed type, number of milking cows, liters of milk sold, milk peak value, total land, and extension visit). Next, the "aggregate" function in the R programme was used to compute the summary statistics of subgroups of a dataset (the statistics of each production feature were treated as a subgroup because each production characteristic was subject to analysis for the number of sample sizes).

3.8 System Development

The peer-to-peer learning prototype was created using a number of equipment as well as software technologies. The developed prototype is implemented using the hardware and software tools.

3.8.1 Software Tools

(i) Integrated Development Environment (IDE)

The IDE used in this study, Android Studio, is the official one for Google's AOS. It is a freeware freely available tool with features that facilitate programming when developing an app (Kamath *et al.*, 2018). The Eclipse IDE can also be used to create a Mobile-based app instead of Android Studio (Verma *et al.*, 2018). Android Studio is recommended over Eclipsedue to its intuitive interface, Gradle integration, robust Java source code auto-completion, reliability of the system, and development process. Version 4.2.2 of Android Studio was usedin this research.

(ii) Android Operating System Smartphones

The Android operating system (AOS) is one of the most popular smartphone platforms. Google's Android mobile operating system is based on the Linux kernel and is widely used in smartphones and tablets (Kamath *et al.*, 2018). The Android mobile operating system has received more customer demand in the last decade than all other smartphones combined. According to data from the Worldwide Market Shares for Mobile Devices Operating Systems, from January 2018 to July 2020, AOS will dominate over 83% of the market for mobile operating systems in Africa (O'Dea, 2021). The 18th edition of Android was used to test the developed peer-to-peer learning application, version 11.

(iii) My-Structured Query Language (MySQL)

My-Structured Query Language (MySQL) is a free Relational Database Management System (RDBMS) that employs Structured Query Language (SQL) at the backend to handle databases (adding, accessing, and maintaining content in a database) (Yan & Chen, 2011). It uses a variety of ways to support system administration by handling sophisticated and high-volume database queries.

The MySQL database works well with the PHP programming language to generate an Application Programming Interface (API) that connects the application to the system's server. It can operate on any operating system (OS), which makes it reliable, robust, and versatile. The advantages of the My-Structured Query Language are data security, on-demand scalability, and excellent performance. The MySQL database was employed for data administration, storing, and access in this study. Furthermore, MySQL provides the database builder with various access levels and an encrypted password to improve security. The MySQL database version used in this study was 10.4.18-MariaDB.

(iv) XAMPP Server

X – Cross-platform (You can run XAMPP on any operating system.)

Apache server (Using a native computer to run PHP scripts)

M- MySQL (MySQL is required to store knowledge in information and to perform information operations).

(v) P- PHP scripting language (to build a dynamic web page)

XAMPP validates clients or your website before uploading it to an online web host. The XAMPP server program on your computer offers a suitable setting to validate MYSQL, PHP, Apache, and Perl projects. The local hosting service employed in this study was XAMPP version 8.0.5.

3.8.2 Hardware Tools

Dell Latitude E7270 with Intel(R) Core i5 processor, CPU @ 2.40GHz, RAM 8.00 GB, SSD 128 storage, and System type 64-bit operating system utilized for software development.

3.9 Mobile Application Development Approach

The scrum method has additional advantages over other Agile development methods since it breaks the project into manageable subtasks and allocates time to complete each subtask. In this instance, it ensures that each task is completed by its due time to meet the deadline.

Moreover, the Scrum methodology allows the team to get together and review the milestones concluded in each subtask. As a result, it made it possible for the authors to get together and talk about all the milestones they had achieved. The steps that make up the Scrum process include product vision, release planning, product backlog, sprint backlog, and possibly shippable product. These procedures were used in this study.

3.9.1 Product Vision

The Product vision describes the Product's potential state and the problems and goals it intends to solve. The study's smallholder dairy farmers and extension workers served as the prototype's product owners and stipulated product vision for the developed prototype. Furthermore,through peer-to-peer sharing of farming knowledge and experience with the assistance of extension officers, explanations were given concerning the application's main goal (to boost milk yield).

3.9.2 Release Planning

Either every sprint, as part of the sprint review, or as part of the routine preparation for the next sprint, release planning takes place in the Scrum method. The customer's value and overall quality should balance against scope, time, and budget constraints during release preparation. The smallholder dairy producers and extension workers (product owners) were included to prepare a release plan for the developed prototype.

3.9.3 Product Backlog

A product backlog is the checklist of product requirements. The user stories were used to identify system requirements. The product backlog's items assisted in attaining the product vision. The product backlog was developed, and product owners such as extension officers and smallholder dairy producers owned it. The product owners then prioritized the items in the product backlog in accordance with value.

3.9.4 Sprint Backlog

The Sprint backlog represents the list of prerequisites that have been tasked with a certain Sprint. The scrum squad defined the sprint backlog's requirements. A development team owned the sprint backlog, and only they were responsible for modifying it. The modules for the developed prototype were identified to ensure that the development met the deadline, and the sprint (time) for completing each backlog was set.

3.9.5 Potentially Shippable Product

The value supplied to customers through product backlog items completed during a sprint is called potentially shippable products (Product incremental). Stakeholders valued each sprint backlog because it allowed them to share their dairy farming skills and expertise to enhance milk yield.

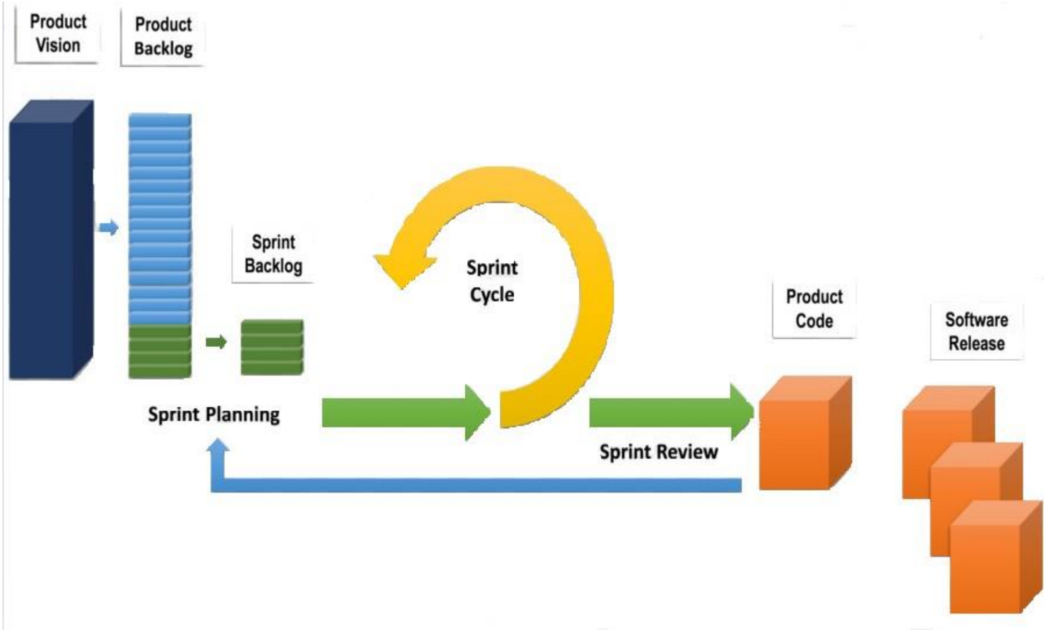


Figure 3: Scrum development model

3.10 Ethical Consideration

The School of Computational and Communication Science and Engineering (CoCSE) at The Nelson Mandela African Institution of Science and Technology in Arusha (NM-AIST) approved ethical conduct. The letter was sent to Kibong'oto Hospital, and an official letter was written from that hospital to Meru District Council. Respondents consent to participate in the data collection process to complete the questionnaire. Furthermore, respondents did not provide personal information, such as names or contact information (email and phone number). Therefore, the information gathered was safe. The research findings are being utilized to automatically place smallholder dairy farmers in the appropriate groups so they may share farming expertise and knowledge to boost milk yields.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Demographic Characteristics

Seventy-eight (78) responses were received from 3 wards (Kikwe, Sing'isi and Akheri) of the Meru District Council in Arusha, with 69 coming from smallholder dairy farmers and nine from extension officers. Thirty-one (31) (45%) of the 69 smallholder dairy producers were female, while 38 (55%) were male. Furthermore, 5 (56%) of the nine extension officers were female, whereas 4 (44%) were male. The number of female smallholders' dairy farmers was lower than male counterparts, and the number of male extension officers was lower than femaleextension officers, which presented a difficulty to the researcher, according to Fig. 4.

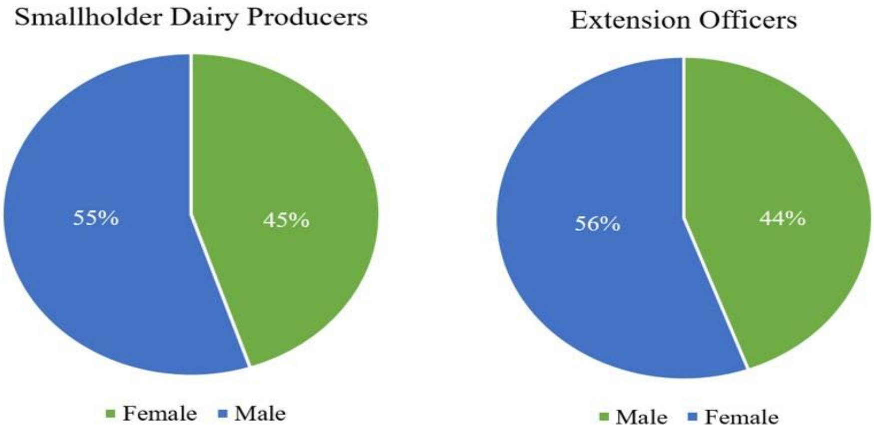


Figure 4: Gender demographic for smallholder dairy producers and extension officers

Furthermore, the researcher chose respondents for smallholder dairy farmers based on their educational backgrounds, which covered primary, secondary, certificate, and diploma levels. Thirty-one (31) (44.9%) of the 69 respondents were female, with eight (8) having completed primary school, 13 having completed secondary school, three (3) having completed a certificate, five (5) having completed a diploma or higher education, and two (2) having completed informal education. There were 38 (55.1%) male smallholder dairy farmers, 11 with primary education, 18 with secondary education, 3 with a certificate, 4 with a diploma or higher, and 3 with no formal education (Fig. 5).

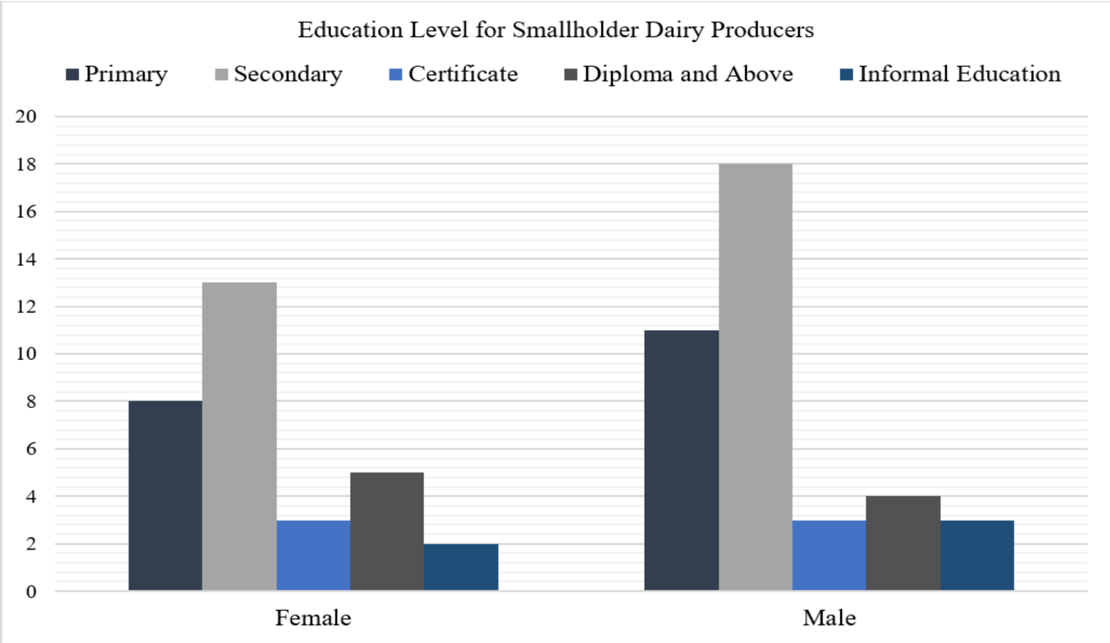


Figure 5: Educational level demographic for Smallholder dairy producers

In addition, the researcher chose respondents for extension officers based on their educational degrees, which included a certificate, diploma, and higher education. The results showed that 5 of the nine (9) extension officers were female, with one female extension officer having a certificate and four female extension officers having a diploma or higher. One of the four male extension officers has a certificate, while the other 3 have a diploma or higher education, as shown in Fig. 6.

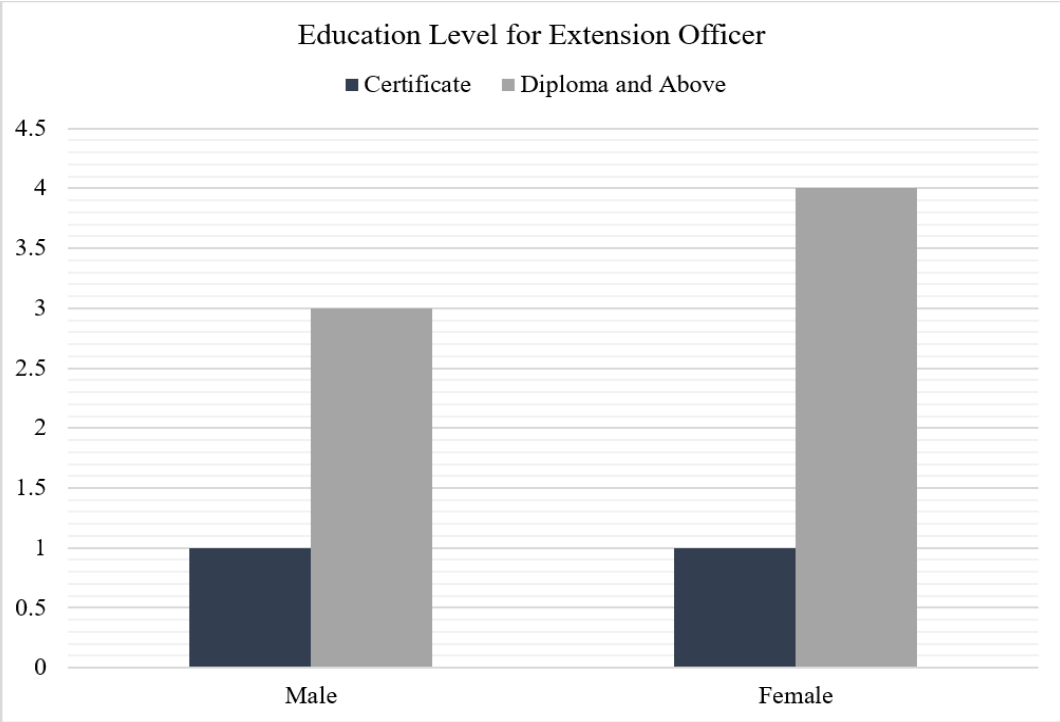


Figure 6: Educational level demographic for extension officers

In addition, respondents for extension workers and smallholder dairy producers were chosen based on their residence locations. The purpose of collecting residence data was to determine the number and address of extension staff assigned to that area to improve extension services to smallholder dairy producers. When smallholder dairy producers want physical support, the residence addresses are used to locate a nearby extension officer who can provide timely assistance. The illustration of smallholder dairy producers' residences is shown in Fig. 7.

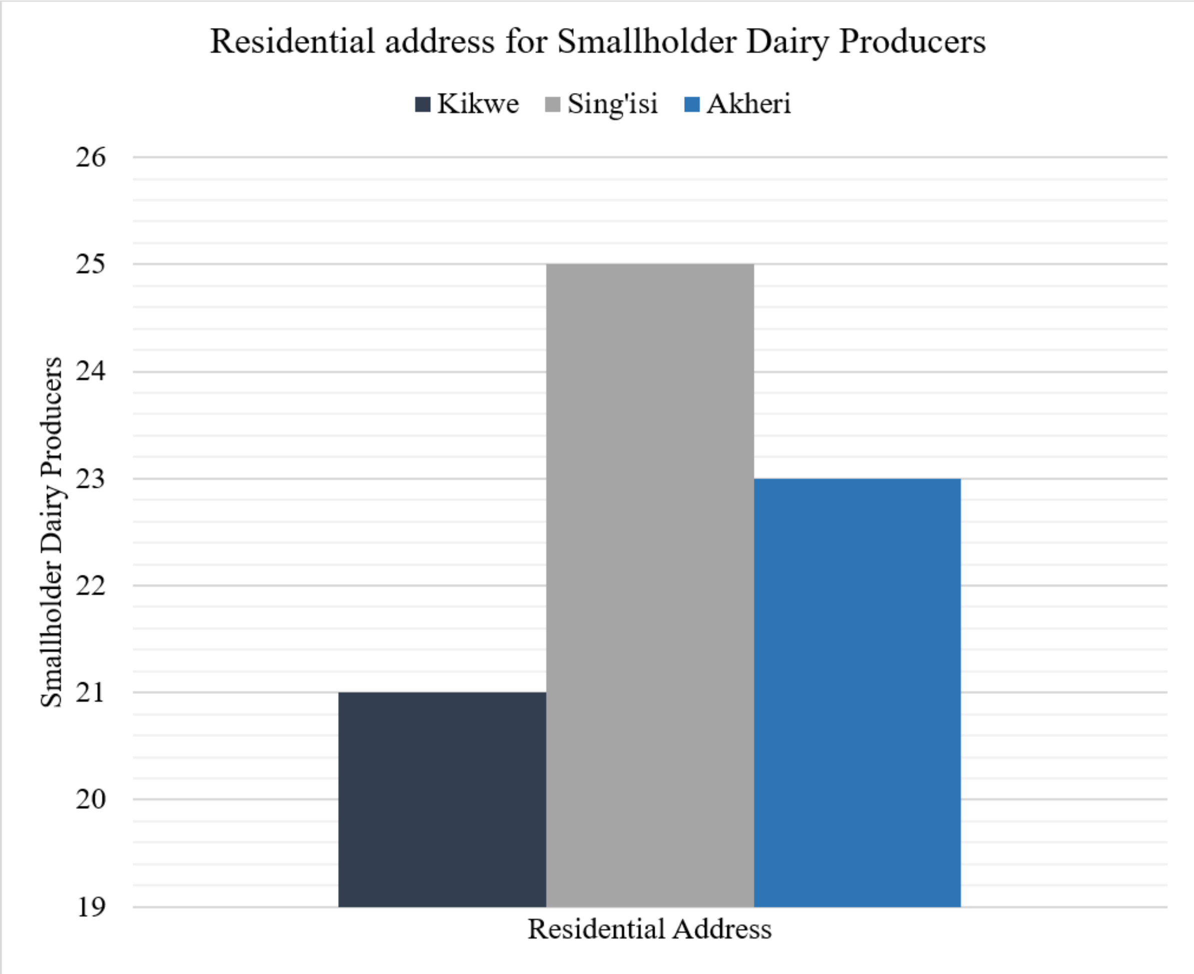


Figure 7: Residential address for smallholder dairy producers

4.1.2 The Methodology Used to Assign Smallholder Dairy Producers to their Clusters

Dairy farmers must consider various approaches and processes and their potential implications as they strive to maximize herd viability through excellent herd management (Brotzman *et al.*, 2015). To assess the overall success of their herds, smallholder dairy farmers can utilise a number of trends, such as reproductive efficiency, cattle well-being, and numerous other farming parameters. This research used 10 production features from prior research (Nyambo *et al.*, 2019). The chosen production elements were picked because of their direct impact on milk yield. The following are the selected ten production features: feeding frequency, feed type, watering frequency, milking frequency, vaccination frequency, frequency of extension officer visit, milk peak value, total land, and litres of milk sold.

(i) Feed type

Feed type was chosen as one of the production aspects since feed is more crucial to any departing organism for growth and energy generation. Therefore, the feed and feeding strategy influences dairy cow productivity and reproduction. Although it may seem simple, proper feeding is a basic necessity for dairy cattle, and changing the feeding frequency has been proven to significantly reduce/ increase the amount of milk produced (Khaskheli, 2020). Furthermore, during lactation, milking cows must consume a lot of food (Humer *et al.,* 2018).

A dietary plan that satisfies a productive dairy cow's nutritional needs is necessary (Erickson & Kalscheur, 2020). Carbohydrates, amino acids, fatty acids, minerals, vitamins, and water are all the nutrients needed for a nursing dairy cow to supply the demand for milk and milk components by the mammary gland. Intake of nutrients, frequency of milking, good feed quality, and ad-libitum water consumption are all crucial factors in enhancing dairy cow performance and output (Khaskheli, 2020). The milk output increase is based on feeding effectiveness, feeding frequency, and milking frequency.

(ii) Feeding frequency

In this study, feeding frequency refers to how frequently smallholder dairy farmers feed their cattle daily. This study used to feed frequency because providing a high volume of feed regularly significantly impacts milk output. Feeding a huge quantity of concentrates is desirable to meet this high calorie and Metabolizable Protein (M.P.) requirement, particularly in early and mid-lactation (Humer *et al.,* 2018). However, milk output increases by about 18% whenever feeding frequency is increased from two meals daily to three times daily, which is economically reasonable. Dairy cow milk production decreases by 70 to 38% when feeding frequency is reduced from two occasions daily to only once daily (Khaskheli, 2020).

(iii) Watering frequency

Watering frequency significantly impacts dairy cow milk yield; as a result, this production characteristic is one of the ten selected production features, indicating the number of times smallholder dairy producers watered their dairy cows. In addition to nutritional usage and milking frequency, high-quality feed and ad-libitum water are always important in improving dairy cow performance and production (Khaskheli, 2020). Dairy cows with high milk production rates have higher demands on water than other land-based livestock. Considering milk is drank in such huge quantities and contained eighty-seven water-based, there is a rise in the need for water (Ali *et al.*, 2015). In this study, animals receiving water twice daily produced less milk (Ali *et al.*, 2015). Dairy cows need to consume sufficient food while drinking enough water to produce the optimal amount of milk. As a result, the timing and frequency with which dairy cows are watered might alter their daily water consumption and demands.

(iv) Milking frequency

This production characteristic refers to the number of times smallholder dairy farmers milk their cows daily in this study. The milk output rises by 30% when the number of milkings is raised from two occasions to three occasions daily. Increasing the milking frequency from two to three times daily boosts milk production (7% to 20%) (Khaskheli, 2020).

(v) Frequency of extension visits and Vaccination frequency

Visits by extension officers regularly in this study refers to the number of times an extension officer visits smallholder dairy producers yearly. Furthermore, vaccination frequency refers to the number of times smallholder dairy producers vaccinate their dairy cows each month. Therefore, the frequency of vaccination corresponds to the number of extension visits, as smallholder dairy producers can receive all of the necessary extension services when an extension worker arrives. One area of dairy cattle farming that requires special attention is health care (Aduna & Ayalew, 2019).

Maintaining the health of dairy cattle is necessary to increase milk yields and profit margins considering the disease represents one of the gravest threats to livestock output. According to researchers, these issues might be resolved by bettering community's livestock sickness surveillance and reporting systems and providing better animal training and prescription delivery systems. Considering potential hazards connected with infectious illnesses and the financial ramifications of illness for livestock owners, it is essential to consider adequate cow veterinary care and preventative measures in these expanding farming systems.

(vi) Total land

In addition, total land was chosen for this study, which refers to the quantity of land used to raise dairy cattle. The habitat for dairy cows is more crucial because bad consideration affects milk output. Maintaining suitable conditions for developing dairy cows requires avoiding excessive environmental impacts, like heat and weather (Lijalem *et al.*, 2015). Farmers may lessen tension on their cattle by providing a quality home and a carefully thought-out farm. Optimizing the surroundings lowers stress and illness risk while making management easier, increasing milk output. One of the crucial productivity aspects of a dairy farming scheme is the availability of appropriate housing.

(vii) Milk peak value and Litres of milk sold

If the preceding production aspects are well practiced, milk peak value and sold litres will be enormous. Therefore, this is how the 10 production features are selected. The allocation of farmers into their relevant clusters was done in this research using a rule-based engine. The rules engine was developed using the milk peak value, one of the 10 production features, where farmers got assigned to specific groups depending on their milk yields.

4.1.3 Performance of Clusters

The performance of each cluster across all production features is summarized in Table 2; mean values were used to calculate performance, and Figure 8 illustrates a graphical representation of cluster performances across all product characteristics.

After the data analysis, the result shows that better and lower performing clusters were indicated through their product feature value in each farming production feature suggested. The production feature considered to differentiate one cluster from the other was the milk peak value. As depicted in Figure 8, the performance for every cluster is realized for every element of the production and for the entire production to determine its place.

According to the analysis, as seen in Fig. 8, the leading cluster has the greatest mean value, the following cluster has the next-highest mean value after the leading cluster in position, and vice versa. This is because cluster positions were identified via the mean value of the particular product features. For example, the production features such as vaccination, feed type, feeding frequency, milking frequency, and watering frequency, extension officers visit them frequently, and they have enough herds for their cattle. Furthermore, a cluster performs worse if fewer smallholder dairy farmers employ those production features greatly.

Table 2: All the production features in all clusters with their values (Field data, 2021)

Production features	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
	Mean value	Mean value	Mean value	Mean value	Mean value	Mean value
Vaccination Frequency	1.56	1.37	2.10	1.99	2.15	2.08
Watering Frequency	2.33	2.21	1.83	1.42	1.67	1.63
No. of Milking Cows	2.30	2.27	2.24	2.13	2.17	2.23
Total land	4.26	5.18	1.86	2.42	2.98	2.23
Liter Sold	12.57	10.39	8.21	6.00	8.13	12.49
Extension Visit	7.55	7.08	4.86	5.32	9.85	9.89
Milk Peak value	14.45	12.57	11.63	9.15	11.08	14.02
Feed Type	3.17	3.09	3.01	1.91	2.38	2.18
Feeding Frequency	2.53	2.42	1.94	1.57	1.60	1.65
Milking Frequency	2.00	1.98	1.70	1.36	1.31	1.27

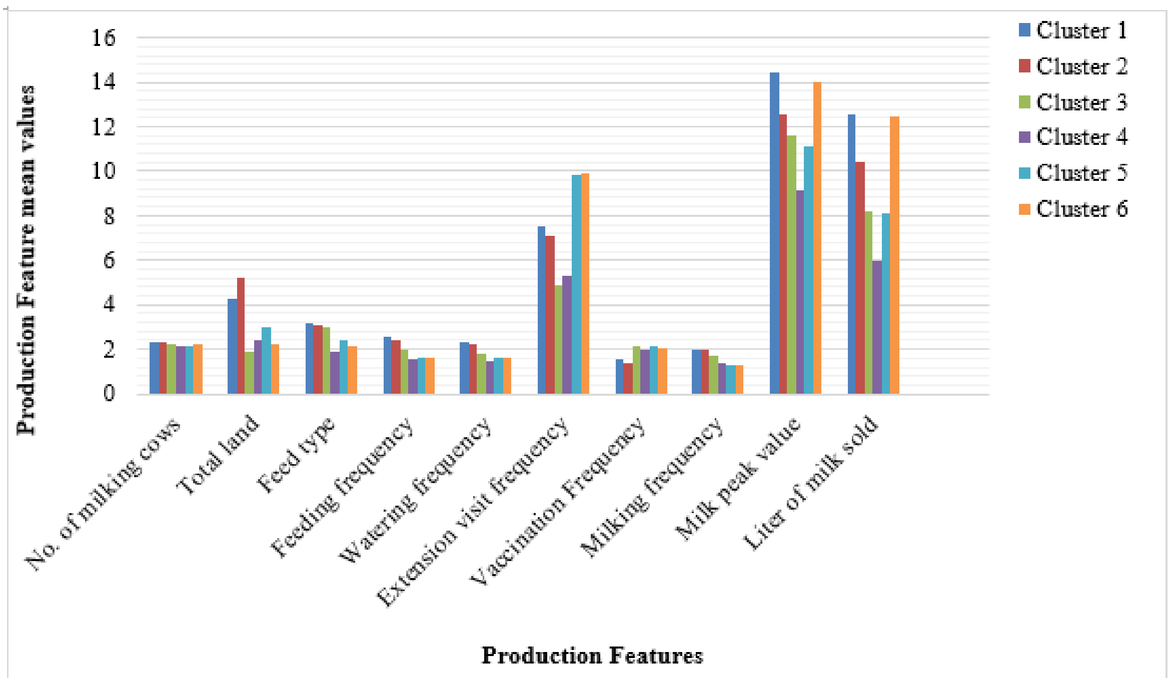


Figure 8: Cluster performance using specific production features

The performance of every group is shown graphically in Fig. 8, along with the top-performing group and vice versa. In most production features, Cluster 1 leads, followed by Cluster 2 and Cluster 3. The lowest-performing clusters are Cluster 5, followed by Cluster 6, then Cluster 4. This indicates that, compared to other clusters, the leading group includes a greater proportion of smallholder dairy farmers who were more adept at implementing production features.

4.1.4 Position of Clusters in Each Production Feature

The location of the cluster on each production feature is displayed in Table 3.

Table 3: Position of the cluster based on its score on each production feature

Production features	**Position of the clusters**					
	Position 1	**Position 2**	**Position 3**	**Position 4**	**Position 5**	**Position 6**
Vaccination Frequency	Cluster-5	Cluster-3	Cluster-6	Cluster-4	Cluster-1	Cluster-2
Watering Frequency	Cluster-1	Cluster-2	Cluster-3	Cluster-6	Cluster-5	Cluster-4
No. of Milking Cows	Cluster-1	Cluster-2	Cluster-3	Cluster-6	Cluster-5	Cluster-4
Total Land	Cluster-2	Cluster-1	Cluster-5	Cluster-4	Cluster-6	Cluster-3
Litre Sold	Cluster-1	Cluster-6	Cluster-2	Cluster-3	Cluster-5	Cluster-4
Extension Visit	Cluster-6	Cluster-5	Cluster-1	Cluster-2	Cluster-4	Cluster-3
Feed Type	Cluster-1	Cluster-2	Cluster-3	Cluster-5	Cluster-6	Cluster-4
Feeding Frequency	Cluster-1	Cluster-2	Cluster-3	Cluster-6	Cluster-5	Cluster-4
Milking Frequency	Cluster-1	Cluster-2	Cluster-3	Cluster-4	Cluster-5	Cluster-6
Milk Peak Value	Cluster-1	Cluster-6	Cluster-2	Cluster-3	Cluster-5	Cluster-4

The results of each production feature, as shown in Table 3, together with its cluster position, are addressed as follows:

(i) Vaccination Frequency

Cluster 4 had the weakest performance, preceding Cluster 1 and Cluster 2, while Cluster 5 had the best performance, then Cluster 3 and Cluster 6. With a mean value of around 2.15, Cluster 5 had a greater vaccination rate than the other clusters; Cluster 2 had the lowest rate, with a mean score of about 1.37. As a result, small-scale dairy farmers in Cluster 5 gained better knowledge about the advantages of immunizing their animals. For more details, see Table 1.

(ii) Watering Frequency

Cluster 1 outperformed Cluster 2, which had a mean score of 2.21, and Cluster 3, which had a mean score of 1.83 in the watering frequency production characteristic. The performance of Cluster 4 was the lowest, with a median score of 1.42, after which came Cluster 6 and Cluster 5 in that order, with mean values of 1.63 and 1.67, respectively. Regarding productivity according to watering frequency, Cluster 1 had a greater mean score. Smallholder dairy producers in Cluster 1 consequently gave their cattle a greater water intake than those in the other clusters. Given that most smallholder dairy farmers are close to water sources, Cluster 1 surpasses Cluster 2.

(iii) Total Land

Cluster 1 came in second with an average of 4.26 acres, and Cluster 2 with a mean score of 2.98 acres, resulting in the top performance. Cluster 2 had a larger total land size for cattle rearing than all other clusters, averaging 5.18 acres. With an average of 1.86, Cluster 3 performed the lowest regarding total land results, followed by Cluster 6 with a mean of 2.23 and Cluster 4 with a mean of 2.42.

(iv) Number of Milking Cows

There are various numbers of milking cows in each cluster. As a result, the farmers in each cluster have between one and three milking cows, a nearly equal number of milking cows. The number of milking cows owned by smallholder dairy farmers varies slightly. However, some have a significant difference in milk production. Therefore, peer-to-peer learning is a compelling option for farmers with a comparable amount of milking cows but radically varied milk production rates since there is such a minor difference in the number of milking cows but a significant disparity in milk output. The mobile-based peer-to-peer learning prototype is particularly useful since smallholder dairy producers with low milk output can learn to increase milk yields.

(v) Litre of Milk Sold

Cluster 1 outsells the remaining clusters regarding weekly milk sales (12.57 litres on average), with Cluster 6 coming in next with 12.49 litres. Regarding weekly milk sales, Cluster 2 has a mean value of 10.39. With weekly milk sales averaging 6.0 litres, Cluster 4 had the worst performance. Cluster 5 came in second with weekly milk sales of 8.13 litres. The 8.21 litres of milk sold per week made up Cluster 3. Cluster 1 is, therefore, the most effective, whilst Cluster 4 is the least effective.

(vi) Frequency of Extension Officer Visits

Cluster 6 performed the best, with an average of 9.89 monthly visits from extension officers, then Cluster 5, with an average of 9.85 monthly visits from extension agents. Extension agents make an average of 7.55 monthly visits to Cluster 1. Cluster 3 had the lowest number of visits from extension agents per month (4.86), followed by Cluster 4 (5.32) and Cluster 2 (7.08). With an average of 9.89 monthly trips, smallholder dairy farmers in Cluster 6 received more veterinary services from extension workers than those in the other clusters. On the other hand, Cluster 3's smallholder dairy farmers experienced fewer extension checkups, on average, 4.86 per month.

(vii) Feed Type

Cluster 1 prevailed over clusters 2 and 3 in this production characteristic, with a mean of 3.17 feed types, demonstrating that smallholder producers provided their cattle with various feeds, including roughage, concentrate, and dietary supplements. The lowest-performing cluster was Cluster 5, which had an average feed type of 2.38. Cluster 6 was next, with a feed type of 2.18, and Cluster 4 was last, with a feed type of 1.91.

(viii) Feeding Frequency

With an average of 2.53 feedings per day, farmers in Cluster 1 had the highest feeding frequency, then Clusters 2 and 3 with an average of 2.42 and 1.94 feedings per day, respectively. On the other hand, cluster 4 had the weakest performance in this production characteristic, with a daily average of 1.65; then came Cluster 5, having a daily average of 1.60, and Cluster 6, having a daily average of 1.65.

(ix) Milking Frequency

With a high milking frequency of nearly 2.0 per day, smallholder dairy farmers in Cluster 1 performed the best in this production characteristic. They were followed by Clusters 2 and 3, with average milking frequencies of 1.98 per day and 1.70 days, respectively. With an average milking frequency of 1.27 daily, Cluster 6 had the worst performance, followed by Clusters 5 and 4, which had intermediate milking frequencies of 1.31 and 1.36 per day, respectively. In light of this, cluster 1 is followed by cluster 2 in the production characteristic of milking frequency. Some smallholder dairy producers in cluster 1 milk their cattle twice or thrice. In contrast, most nearby clusters of smallholder dairy farmers only milked their cows once or twice daily.

(x) Milk Peak Value

Cluster 1 performed highest in production, having smallholder dairy farmers producing more milk at its peak value on average at 14.45 litres daily. Cluster 6 came next, averaging a litre of the milk peak value of 14.02 every day, then cluster 2, averaging a litre of the milk peak value of 12.57 per day. The milk peak value for Cluster 4 was the least at 9.15 litres each day, and Cluster 5 had the highest at 11.08 litres per day. Cluster 3 came in lowest, with a daily milk peak of 11.63 litres. Cluster 1's smallholder dairy farmers produced more milk than the other clusters, leading to a higher milk peak daily value. Contrarily, Cluster 4 has smallholder dairy farmers who produce low quantities of milk and hence have low daily peak values.

4.1.5 Overall Cluster Performance for All Production Features

The overall cluster performance was computed using mean (of means) to establish which cluster is the overall best performer, which cluster is the next best performer to all production features, and so on. The mean of means is calculated using the formula (see Equation iii).

$$\mu_X = \left(\frac{m1 + m2 + m3 + ... + mn}{N}\right) \quad \text{(iii)}$$

Where: **μ** stands for the mean of means

m stands for means

N stands for **the** number of means

The calculation revealed that Cluster 1 was the best-performing cluster, followed by Cluster 2 and 6. Cluster 5 was the poor-performing cluster, followed by Clusters 3 and 4. Based on these findings, the best smallholder dairy producers were assigned to the best-performing clusters and vice versa. The mean of means was calculated based on the means of each production feature in every cluster. The mean of means presents the overall mean of all the production features in each cluster; for this case: the overall mean of means was used to measure the overall cluster performance.

Based on the results of data analysis as shown in Fig. 7, Cluster 1 was the best performer of all to the majority of product features with 53%, followed by Cluster 2 (49%), then by Cluster 6 (47%). The result indicates that Cluster 1 has a vast number of smallholder dairy producers who produce more milk compared to other clusters since smallholder dairy producers in Cluster 1 were doing best in the majority of production features. Moreover, the results show that the lower-performing clusters were Cluster 5 (43%), followed by Cluster 3 (39%), then Cluster 4 (33%). This means that these lower-performing clusters were poorly practicing production features that directly impact milk yields, such as feed type, feeding frequency, milking frequency, vaccination, extension visit, and total land.

Figure 9 depicts overall cluster performance; smallholder dairy producers with high milk outputs are assigned to the cluster with the best performance (meaning that the best-performing smallholder dairy producers in milk yield are given to the best-performing cluster and vice versa).

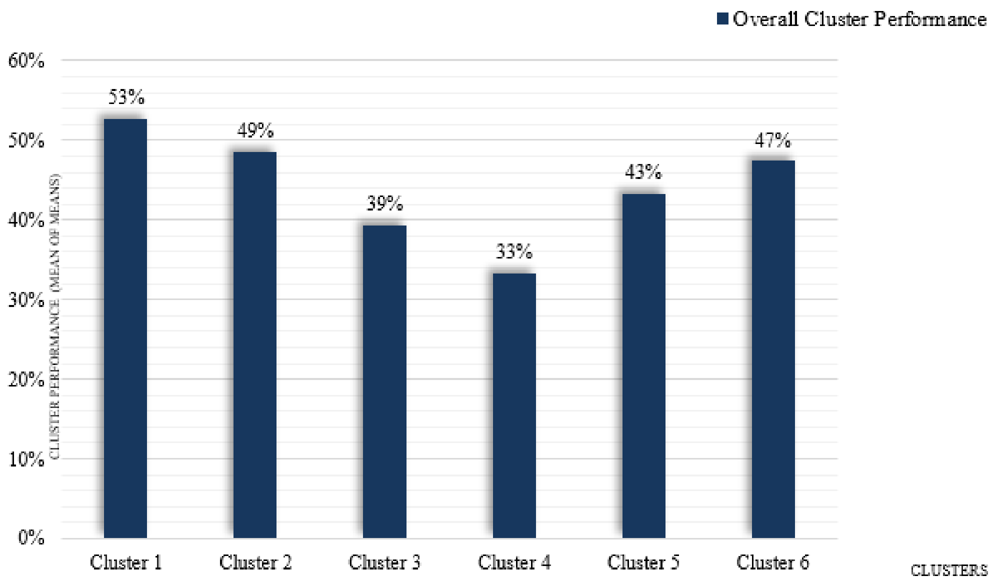


Figure 9: Overall cluster performance (using mean of means)

4.1.6 Profiling of Smallholder Dairy Producers

Smallholder dairy producers' profiling is based on the 10 extracted production features, which are; the number of milking cows, total land, extension visit frequency, vaccination frequency, watering frequency, feed type, feeding frequency, milking frequency, a litre of milk sold, and milk peak value. All the clusters have the same production features and components except for the milk peak value, where each cluster has a different value; this production feature was used for smallholder dairy farmer allocation to their belonging clusters. The scale (range for milk peak value) was created using data acquired at NAIC 2021 (unpublished) on milk production capacity per cow. According to the study, a crossbred cow can produce up to 30 litres of milk per day and up to 5 litres per day. Table 4 shows the scale (range for milk peak value) used for smallholder dairy producers profiling and assigning them to their respective clusters.

Table 4: Milk peak value scale (Range) for Cluster assignment

S/N	Cluster	Milk peak value scale (Range in litres per day)
1	Cluster 1	26 – 30
2	Cluster 2	21 – 25
3	Cluster 6	16 – 20
4	Cluster 5	11 – 15
5	Cluster 3	6 – 10
6	Cluster 4	1 – 5

Cluster assignment is based on the milk peak value (litres of milk yield per day). Where each cluster has its range of litres of milk, for best production performing cluster is assigned 26 – 30, followed by 21 – 25, then by 16 – 20, and the lower production performing cluster is assigned 11 – 15, followed by 6 – 10 then by 1 – 5. Of course, smallholder dairy producers might have the same production features components in almost all the production features. Still, once they differ in milk peak value (litre of milk yield per day), these smallholder dairy producers should be in different clusters as the range indicates.

4.1.7 Production Features with their Components

The production features and their mean values that are utilized to distinguish one cluster from another are addressed in this subsection. Table 5 lists the production features employed in this study, the components (values) of each feature and the components' respective possession. The components of the production features specify the differences across clusters based on the ownership of production features. The production features component displays the production features each cluster has. Furthermore, the milk peak value is the only production parameter in which each cluster has a unique component. Therefore, cluster assignment is based on the milk peak value, a production attribute.

Table 5: Production features and their values

S/N	Production features	Components of the Production Features	Cluster possession of the production feature's components
1	Number of milking cows	1 2 3 4 5	All clusters possess the same production features and components.
2	Total land (Hectare)	Smallholder dairy producer has to specify the land size in hectare	All clusters possess the same production features and components.
3	Feed type	Roughages Roughages and Concentrate Roughages and Supplements All food type	All clusters possess the same production features and components.
4	Feeding frequency (per day)	Once Twice Trice More than trice	All clusters possess the same production features and components.
5	Watering frequency	Once Twice Trice More than trice	All clusters possess the same production features and components.
6	Extension visits frequency (per year)	0 1– 14 15 – 28 29 – 42 43 – 56 57 – 70 71 – 84	All clusters possess the same production features and components.
7	Vaccination frequency (per month)	0 1 – 2 3 – 4 5 – 6 7 – 8	All clusters possess the same production features and components.
8	Milking frequency	Once Twice Trice	All clusters possess the same production features and components.
9	Litre of milk sold (per week)	0 1– 26 27 – 52 53 – 78 79 – 104 105 – 130 131 – 156	All clusters possess the same production features and components.

4.2 System Requirements

Functional and non-functional requirements are the two types of system requirements. Functional requirements are discussed in the following order and depend on the system module.

4.2.1 System Administration and Management for Extension Officers and Smallholder Dairy Producers

(i) Functional Requirements

The functional requirements for system administration and management module for extension officers and smallholder dairy producers are discussed as follows:

(a) Extension Officers

- The developed solution should be capable of permitting the system admin to register an extension officer.
- Extension officers registered in the system by providing the following information Officer-ID, first name, last name, email, and designation.
- The developed solution should be capable of permitting an extension to login into the system using an email and password.
- The system should enable the extension officer to edit their information in the database. The information to be edited is the username and password when one wishes to change them.
- The system should enable extension officers to view the list of farmers in the same cluster.

(b) Smallholder Dairy Producers

- The developed solution should be capable of permitting smallholder dairy producers to register into the system. For example, a farmer registered in the system with the following information name, email, password, phone number, and location.
- The developed solution should be capable of permitting smallholder dairy producers to login into the system using an email and password.

- The developed solution should be capable of permitting smallholder dairy producers to edit their information in the database. The information to be edited is the username and password when one wishes to change them.
- The system should enable smallholder dairy producers to view the list of other producers in the same cluster.

4.2.2 Production Features Management

(i) Functional Requirements

The functional requirements of the production features management module for smallholder dairy producers are discussed as follows:

(a) Feed Type

- The developed solution should be capable of permitting smallholder dairy producers to add a feeding type.
- The developed solution should be capable of permitting smallholder dairy producers to edit the existing feed type.
- The developed solution should be capable of permitting smallholder dairy producers to view all lists of feeding types.

(b) Feeding Frequency

- The developed solution should be capable of permitting the smallholder dairy producers to add feeding frequency by specifying the value of the frequency.
- The developed solution should be capable of permitting smallholder dairy producers to edit and update the feeding frequency value.
- The developed solution should be capable of permitting smallholder dairy producers to view all lists of feeding frequencies.

(c) Watering Frequency

- The developed solution should be capable of permitting smallholder dairy producers to add watering frequency by specifying the value of the frequency.
- The developed solution should be capable of permitting smallholder dairy producers to edit and update the existing watering frequency value.
- The developed solution should be capable of permitting smallholder dairy producers to view all lists of watering frequencies.

(d) Vaccination Frequency

- The developed solution should be capable of permitting smallholder dairy producers to add vaccination frequency by specifying the value of the frequency.
- The developed solution should be capable of permitting smallholder dairy producers to view all lists of vaccination frequencies.
- The developed solution should be capable of permitting smallholder dairy producers to delete existing vaccination frequency.

(e) Milking Frequency

- The developed solution should be capable of permitting smallholder dairy producers to add milking frequency by specifying the value of the frequency.
- The developed solution should be capable of permitting the smallholder dairy producers to edit and update the existing milking frequency value.
- The developed solution should be capable of permitting smallholder dairy producers to view all lists of milking frequencies.

(f) Extension Officer Visiting

- The developed solution should be capable of permitting the smallholder dairy producers to add visiting frequency by specifying the value of the frequency.

- The developed solution should be capable of permitting the smallholder dairy producers to edit and update the existing visiting frequency value.

- The developed solution should be capable of permitting smallholder dairy producers to view all visiting frequency lists.

(g) The number of milking cows

- The developed solution should be capable of permitting smallholder dairy producers to add the number of milking cows by specifying the value.

- The developed solution should be capable of permitting smallholder dairy producers to edit and update the existing number of milking cows.

- The developed solution should be capable of permitting smallholder dairy producers to view all lists of several milking cows.

(h) Total land

- The developed solution should be capable of permitting the smallholder dairy producers to add total land for farming by specifying the land size.

- The developed solution should be capable of permitting the smallholder dairy producers to edit and update the existing range area (land size).

(i) Milk Peak Value

- The developed solution should be capable of permitting smallholder dairy producers to add a quantity of milk yield daily by specifying the amount of milk yield in liters.

(j) Litre of Milk Sold

- The developed solution should be capable of permitting smallholder dairy producers to add the quantity of milk sold per week.

- The developed solution should be capable of permitting smallholder dairy producers to edit the existing quantity of milk sold.

4.2.3 Cluster Management

(i) Functional Requirements

The functional requirements of the cluster management module for smallholder dairy producers are discussed as follows:

(a) Smallholder dairy producers ranking

The system should graph several trends of production performance for smallholder dairy producers for personal evaluation based on production.

(b) Adding a new cluster

The developed solution should be capable of permitting the system administrator to add a new cluster by specifying the name of the cluster.

(c) View list of clusters

The developed solution should be capable of permitting the system administrator to view other clusters available in the system.

(d) Assign features to the cluster

The developed solution should be capable of permitting the system administrator to assign different features to the specified cluster.

4.2.4 System Notification

The functional requirements of the system notification module for smallholder dairy producers are discussed as follows:

(i) Chatting

The developed solution should be capable of permitting smallholder dairy producers to send messages to each other to exchange knowledge within the same cluster or with other members in other clusters.

(ii) Notification

The developed solution should be capable of permitting the smallholder dairy producers to receive notifications that suggest the smallholder dairy producer have higher milk yields.

4.3 Non-Functional Requirements

Non-functional requirements define the quality characteristic of a software system, and they are a set of criteria used to assess how well a system performs in various situations (Guru99, 2022). A non-functional requirement ensures the software system's overall usability and efficacy. Conversely, non-functional requirements that aren't met can lead to systems that don't meet user expectations. Table 6 shows a list of identified non-functional requirements.

Table 6: Non-functional requirements

S/N	Requirements	Descriptions
1	Confidentiality	Secret information is safeguarded from unwanted disclosure with the mobile-based peer-to-peer learning prototype.
2	Integrity	The system should verify that the data is authentic, correct, and protected against unauthorized user alteration.
3	Availability	The mobile-based peer-to-peer learning prototype assures that users can access the system whenever needed.
4	Performance	The system should be able to accommodate a large number of users while supporting several stations at the same time.
5	Flexibility	The developed solution should be capable of permitting the admin to add new extension officers, clusters, and production features. In addition, it should reallocate the smallholder dairy producer whenever it meets the requirements of being relocated.
6	Usability	The system should be simple to use to fulfil the desired goals successfully and efficiently.
7	Efficiency	The system should be capable of completing the work at the desired speed.

4.4 System Design

System design involves the task of identifying a system's various elements, such as its architecture, modules, and components, as well as its numerous interfaces with the data it processes. The following is a detailed explanation of each aspect.

4.4.1 Conceptual Design

The conceptual design was created after assessing and evaluating the functional and non-functional requirements for the proposed system. As a result, four components (modules) were included in the mobile-based peer-to-peer learning prototype for smallholder dairy producers. The four modules of the mobile-based peer-to-peer learning prototype are system administration and management for smallholder dairy producers and extension officers and production features management, cluster management, and system notification. In system administration and management for smallholder dairy producers and extension officers' modules, the developed solution should be capable of permitting the system admin to register the extension officers.

In addition, the developed solution should be capable of permitting smallholder dairy producers to register into the system. After the registration, smallholder dairy producers and extension officers can change their passwords. The developed solution should be capable of permitting the system admin to add, view, and edit production features to clusters in the production feature management. The system should also allow the smallholder dairy producer to enter the quantity of milk once a day to keep a record that may be used to relocate the smallholder dairy from one cluster to another once a month if it qualifies. The cluster management module handles all cluster-related concerns. The developed solution should be capable of permitting the administrator to add clusters and view and change all cluster-related information. The system notification module controls all system notifications, such as smallholder dairy producer recommendations to learn from the top-performing milk yield in a given cluster. Smallholder dairy producers should also be able to receive, view, and delete notifications through the system, as shown in Fig. 10.

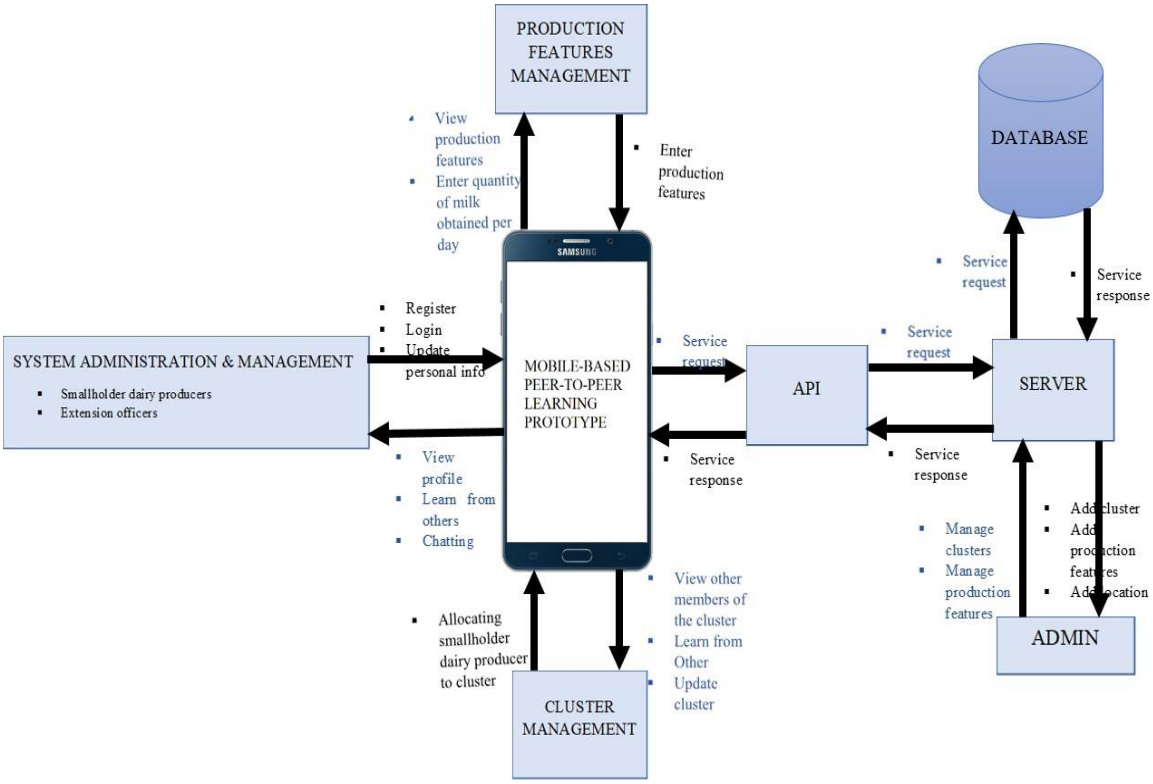


Figure 10: Conceptual design for the mobile-based peer-to-peer learning prototype

4.4.2 Use-Case Diagram

A use case visualizes how a user might interact with the system (Beimel & Kedmi-Shahar, 2019). Actors and use cases are used in use case diagrams to model a system's functioning (SmartDraw, 2022). A use case is a set of actions, services, and operations the system must do. Smallholder producers, extension officials, and system administrators are the three actors who interact with the mobile-based peer-to-peer learning prototype, as shown in Fig. 11.

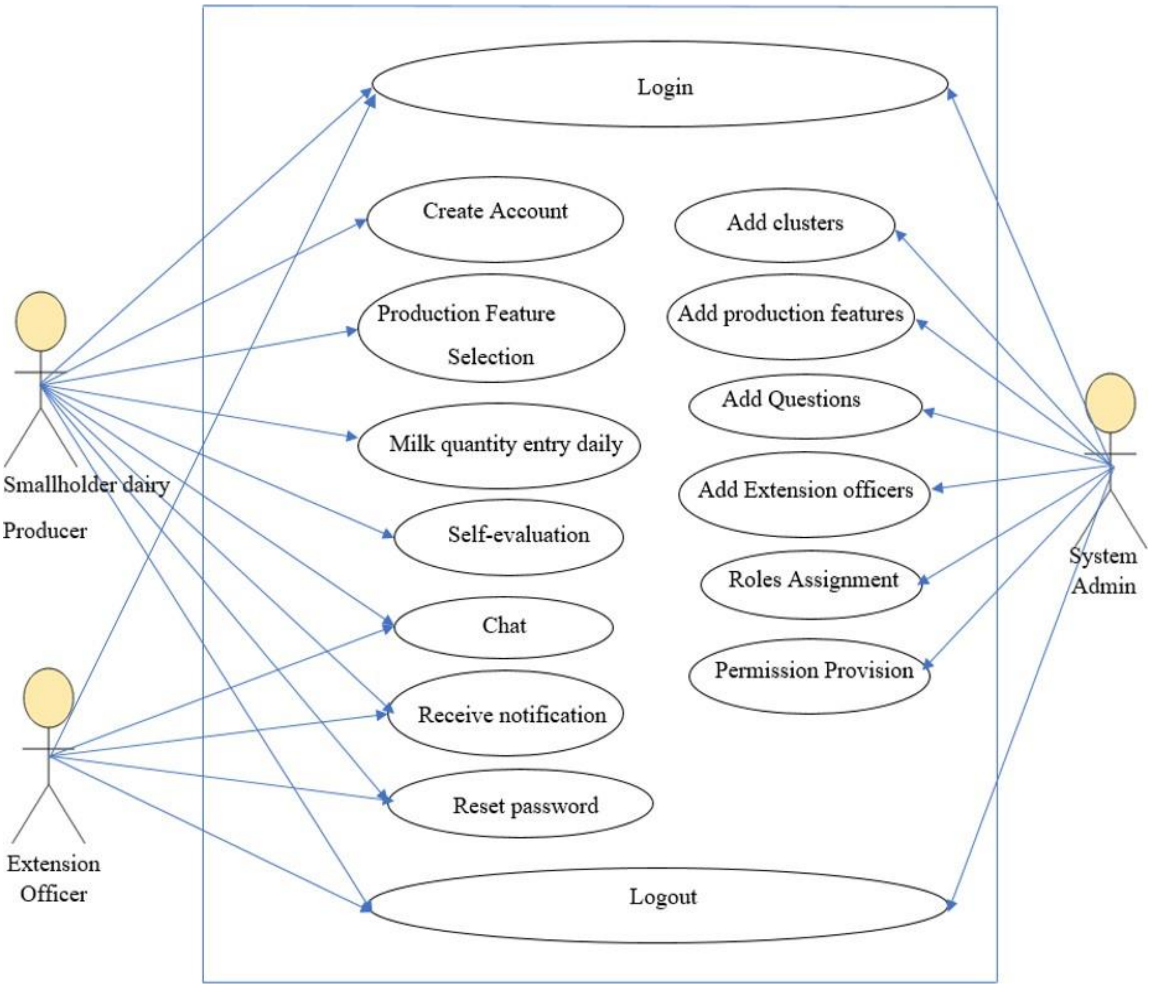


Figure 11: Use-case diagram of the mobile-based peer-to-peer learning prototype

4.4.3 Database Design

Database Design is offered in this work to provide logical and physical models of the suggested database system. The diagram depicts the logical connections between the database's tables. The logical model focuses on the data requirements and the data that will be stored. In contrast, the physical data design paradigm entails converting the database's logical architecture to physical media using hardware and software components. Avoiding data redundancy, meeting user requirements, and having excellent performance are the key benefits of database design (Naeem, 2021). The database design for the mobile-based peer-to-peer learning prototype is shown in Appendix 4.

4.4.4 Data Flow Diagram

The Data Flow Diagram (DFD) depicts the flow of information among actors and system components such as user registration, profiling, clustering, self-assessment, notification, chatting, profile update, changing password, and monitoring and evaluation (Ibrahim, 2010). For example, the data flow diagram for the mobile-based peer-to-peer learning prototype is shown in Fig. 12.

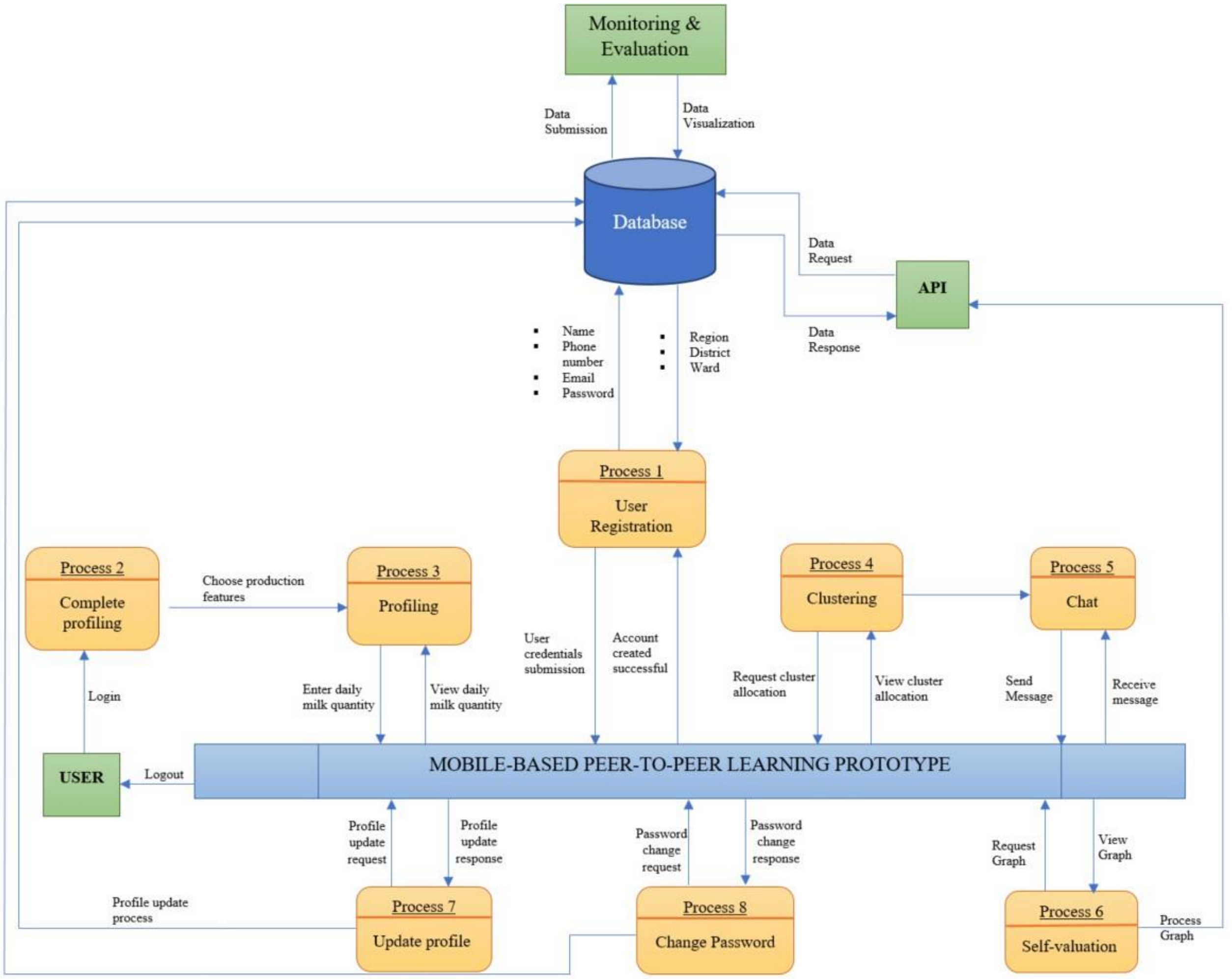
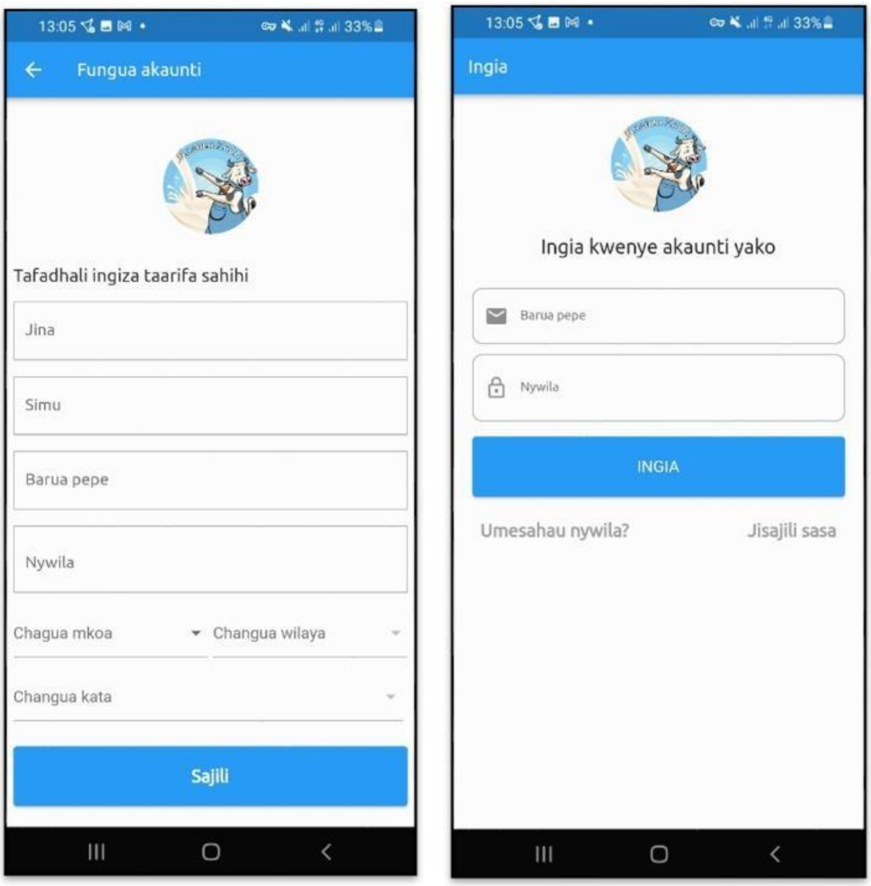


Figure 12: Data flow diagram

4.4.5 Graphical User Interface

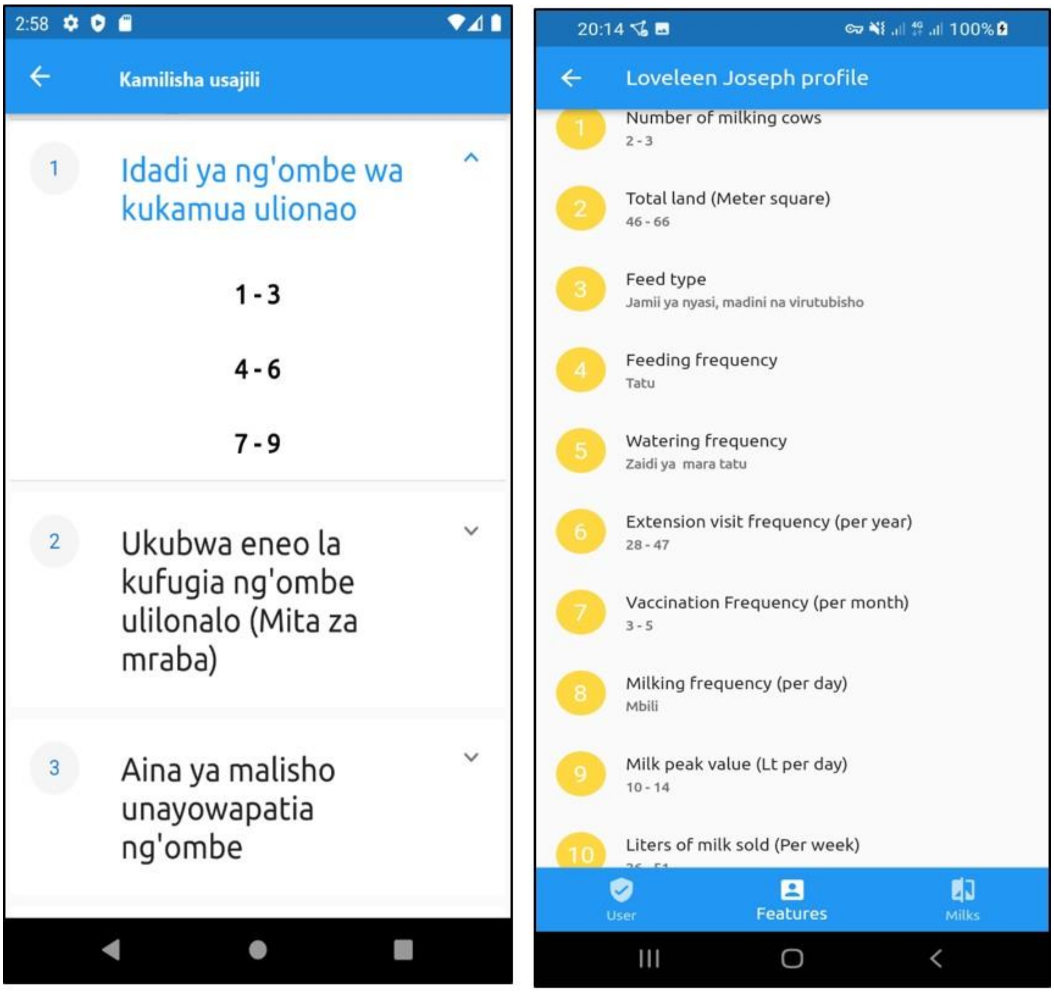
The graphical user interface (GUI) was designed for smallholder dairy producers and stakeholders to interact with the mobile-based peer-to-peer learning prototype used in this study. Users can register for the system by entering their names, phone numbers, email addresses, passwords, and addresses using the GUI (region, district, and ward). The user registration form is depicted in Fig. 13 (a). Furthermore, the user can use the GUI to log into the mobile-based peer-to-peer learning prototype by entering the login credentials (email and password) used during registration. The login page is depicted in Fig. 13 (b).



(a) (b)

Figure 13: (a) is the registration form for smallholder dairy producers, and (b) is the login screen for smallholder dairy

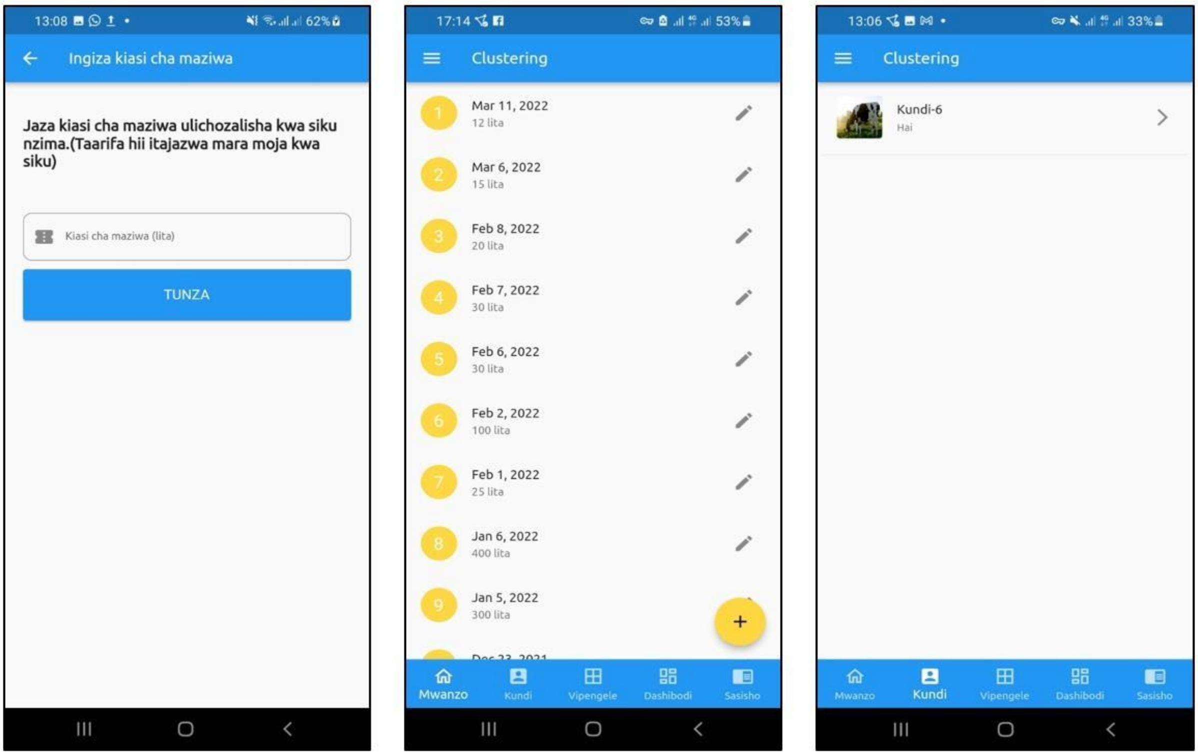
After logging in, the next step is to complete the profile, which entails smallholder dairy farmers answering ten (10) questions about their dairy farming operations and providing ten (10) production features. Figure 14 (a) lists 10 production features regarding questions. Finally, all of the smallholder dairy producer's selections are displayed for simple tracking and self-evaluation by comparing them to the choices of other smallholder dairy producers in the same cluster. Figure 14 (b) shows smallholder dairy producers' production features choices.



(a) (b)

Figure 14: (a) is the screen that shows the details to be given by smallholder dairy producers for profiling, and (b) is the screen that shows the details fed by smallholder dairy producers for profiling

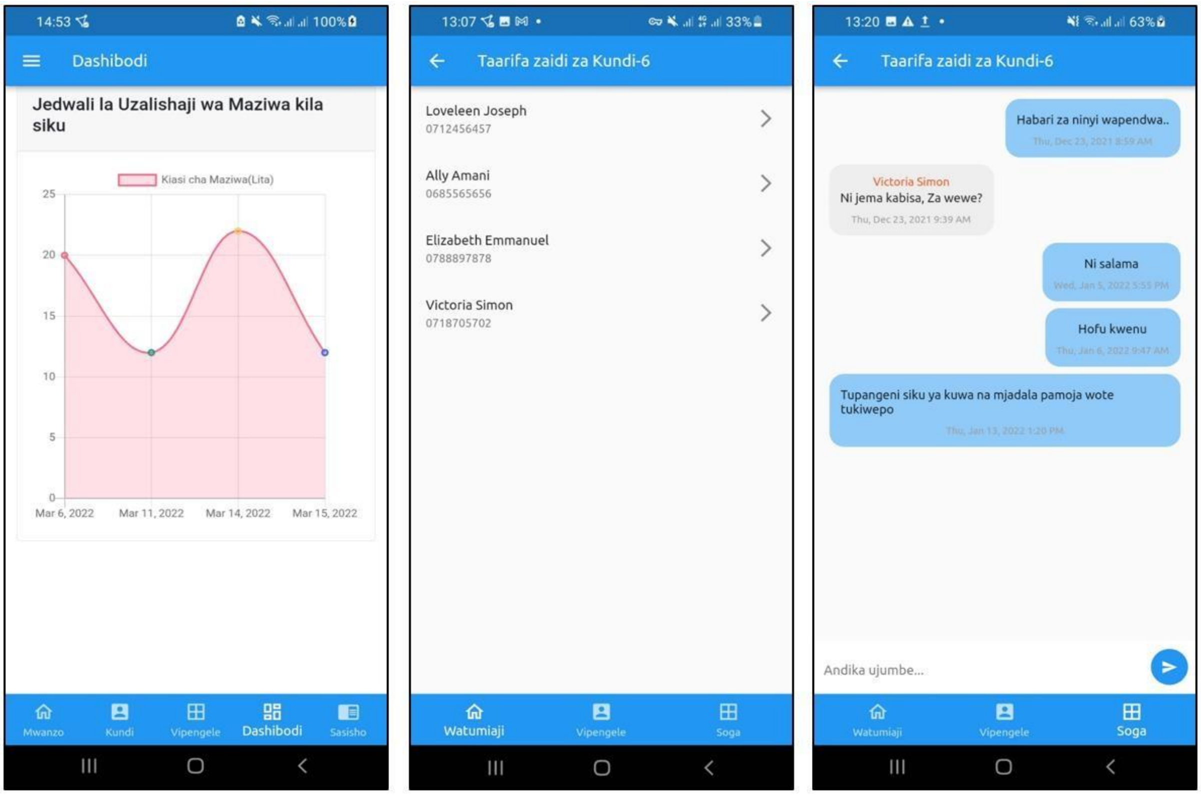
The next step is for smallholder dairy producers assigned to a cluster, after which they must enter their milk quantity (the daily amount they acquire). The page for entering the amount of milk collected in a day is shown in Fig. 15 (a). The records of a smallholder dairy producer's daily milk yield can be viewed to track milk yield performance conveniently; see Fig. 15 (b). Furthermore, the smallholder dairy producer is automatically assigned to their belonging cluster through the mobile-based peer-to-peer system based on milk yield at first and after a month. Figure 15 (c) depicts a smallholder dairy producer assigned to a cluster. Smallholder dairy producers enter milk quantity once a day. After one month, the mobile-based peer-to-peer learning prototype calculates the average milk collected. It shifts smallholder dairy producers to the appropriate cluster if they meet the criteria (if their milk yields fit to be to another cluster).



(a) (b) (c)

Figure 15: (a) shows the daily data entry screen for milk obtained, while (b) is a daily milk record screen, and (c) shows the cluster assignment

Once the smallholder dairy producer is assigned to the cluster can evaluate themselves in terms of milk yield based on the daily milk quantity data records. Figure 16 (a) depicts thesmallholder dairy producer's performance in terms of daily milk yield. Within the cluster, the smallholder can view other members of the same cluster as shown in Fig. 16 (b). Furthermore, in collaboration with other stakeholders in the same cluster, smallholder dairy producers can discuss all aspects of dairy farming, including dairy farming techniques, to boost milk yield showing members of the cluster chatting as shown in Fig. 16 (c).



(a) (b) (c)

Figure 16: (a) shows the allocation of the smallholder dairy producer to the cluster and the shifting of smallholder dairy producers to another cluster based on milk yield. In addition, (b) shows other members of the cluster. (c) shows a chatting room where smallholder dairy producers share knowledge

4.4.6 System Architecture

A system architecture is a conceptual model that specifies a system's structure, behavior, and other aspects (Jaakkola & Thalheim, 2011). Figure 17 depicts the mobile-based peer-to-peer learning prototype architecture, which shows the system's structure and behavior and how stakeholders (smallholder dairy farmers and extension officials) interact.

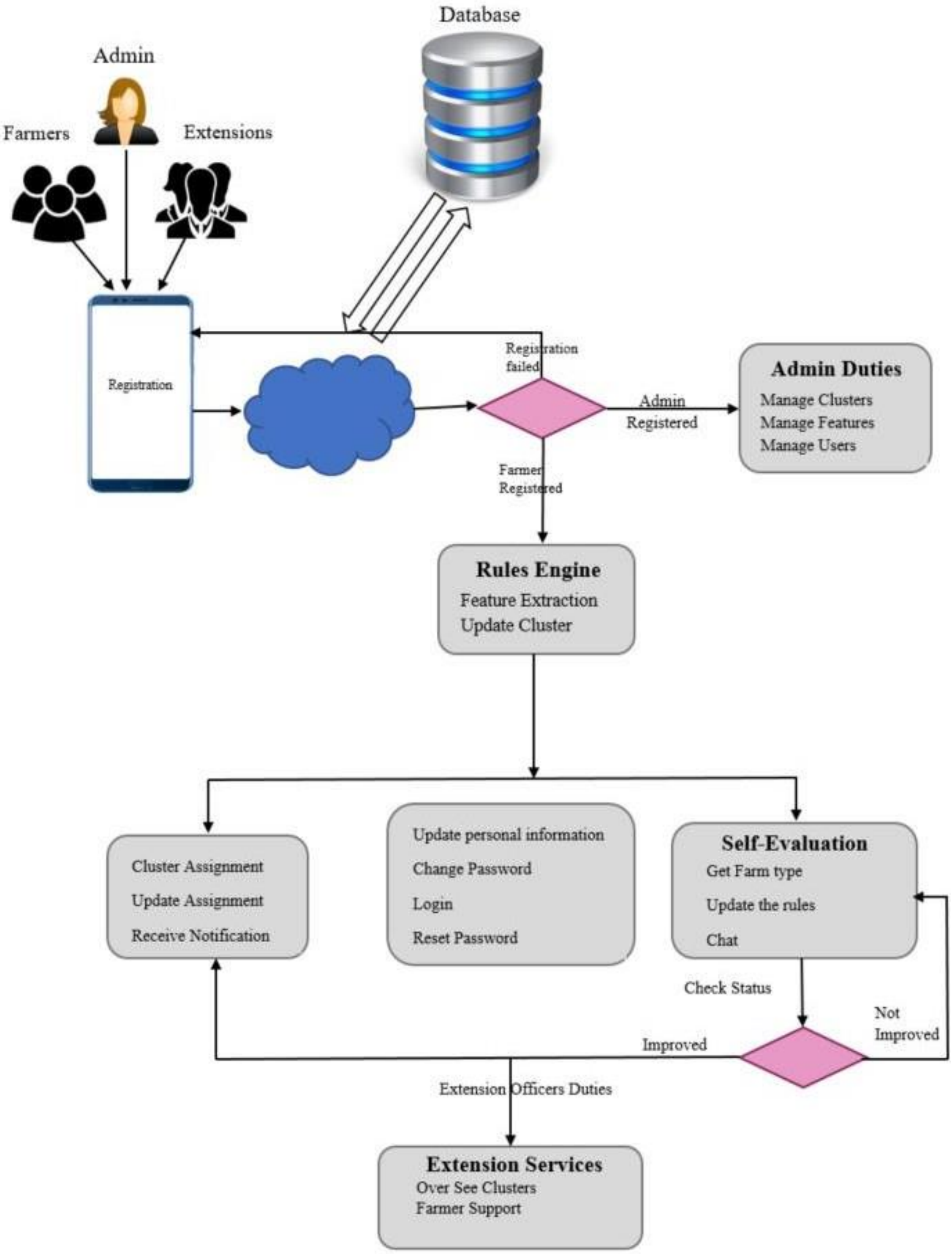


Figure 17: Mobile-based peer-to-peer learning prototype architecture

(i) Components of the system architecture

(a) Registration

Extension officers, together with smallholder dairy producers, do registration. Extension officers will register by providing full names, phone numbers, areas of specialization, and passwords. In contrast, smallholder dairy producers register by providing credentials such as full names, phone numbers, and passwords. The second registration phase provides information about farming through production features information provision based on the questions asked. 10 production features are used in these six (6) clusters: the number of milking cows, total land, Feed type, feeding frequency, watering frequency, milk peak value, a litre of milk sold, extension visit frequency, and vaccination frequency. Each production feature has its value; the value of 9 production features is similar to both clusters except with the milk peak value feature, which is used to differentiate one cluster from the other. Milk peak value has a differentrange, each representing a certain cluster based on cluster production performance. The valuesfor milk peak value are as follows; 1 – 5, 6 – 10, 11 – 15, 16 – 20, 21 – 25, and 26 – 30, wherethe value with a higher range is assigned to the best-performing cluster, the following value with high range is assigned to the following best-performing cluster and the vice versa.

The data analysis and interpretation of cluster performance shows that the leading cluster in Cluster 1 is in line with Cluster 2, followed by Cluster 6. Furthermore, the lower-performing cluster is Cluster 4, in line with Cluster 3, followed by Cluster 5. Therefore, when a farmer puts a range of 1 – 5 as their milk peak value, then an automatic farmer is allocated in cluster 4, as this is the lowest-performing cluster and the lowest milk peak value according to the range given.

(b) Rules Engine

A rules engine is a system that performs actions based on specific conditions configured during runtime (Gefroh, 2020). After a smallholder dairy farmer register to the system, the rules-based engine has to exact the production features and allocate the farmer to their specific production cluster. Smallholder dairy producers must provide farming information based on the 10 production features. Other production features have similar values to all clusters, which means the values of each specific cluster are similar except for the milk peak value, where each cluster has a different value.

Based on this study, the milk peak value is taken as the condition configured during the runtime; based on the range chosen by the smallholder dairy farmer, the specified conditions allocate the farmer to their belonging cluster. The values for milk peak value are as follows; 1 – 5, 6 – 10, 11 – 15, 16 – 20, 21 – 25, and 26 – 30, where these values are assigned to clusters based on the cluster performance. 26 – 30 for Cluster 1, 21 – 25 for Cluster 2, 16 – 20 for Cluster 6, 11 – 15 for Cluster 5, 6 – 10 for Cluster 3 and 1 – 5 for Cluster 4. All people with milk production value, which ranges between 26 – 30, will be assigned to cluster 1 as they are considered best performers and others as the cluster value assigned.

(c) Update cluster

Farmers have to feel some information about the production features after registering, and depending on the milk peak value; farmers must place it in their belonging cluster where they may watch what other fellows (peers) are doing in farming. Farmers also can learn from one another in the cluster with the main goal of improving milk yield. Every time a new farmer registers and is placed in their specific cluster, the cluster is updated with a new member added. The update process will occur during registration time and after the farmer has made any improvement based on milk production.

(d) Self-evaluation

In the self-evaluation phase, smallholder dairy producers evaluate themselves by comparing their production performance with their peers. If a smallholder dairy producer finds out that production is not promising, they can decide whether or not to learn from peers by getting a farm-type to those who desire to learn. On the other hand, if a smallholder dairy producer is not ready to adopt the rules, their peers can keep on with their own rules. Besides, the smallholder dairy producers must adapt the rules they wish to practice to increase milk yield.

After adopting the rules, the smallholder dairy farmer has to observe if there is any positive impact on milk production; if there is no improvement, the same rules are applied. Additionally, when there is an improvement in milk yield compared to the previous production, the system checks the updates to see if the smallholder dairy farmer qualifies to be located in another cluster. A smallholder dairy producer has to keep records of milk production, and after a month, the system has to check whether the farmer qualifies to move to another cluster. The milk peak value is the feature considered the cluster assignment factor.

4.5 System Testing

The v-model system testing is done in three phases: unit testing, integration testing, and entire system testing.

4.5.1 Unit Testing

Unit testing is code-level testing that aids in the early detection of bugs, and It's most commonly utilized to assess each functional unit separately (Nidhra & Dondeti, 2012). For example, the functional components of the mobile-based peer-to-peer learning prototype were unit tested, including user registration, login, cluster assignment, complete profiling, and graph visualization. On the other hand, unit testing does not catch all errors; module-by-module testing was performed to ensure that it met the criteria, and developers only perform the unit testing step because it requires analyzing source code.

4.5.2 Integration Testing

Integration tests were performed to guarantee that the system's internal modules could cohabit and communicate (Nidhra & Dondeti, 2012). Several functional units or groups of working units are integrated and tested to determine if they are properly working. The validation of two or more joined functional components of the system that are integrated to work together properly is called an integration test. Four experts performed integration testing where different mobile-based peer-to-peer learning prototype modules were tested, as shown in Table 7.

Table 7: Integration test results

S/N	Functional Requirements	Test Results
1	Extension officers' registration to the Mobile-based peer-to-peer learning prototype.	SUCCEEDED
2	Extension officers log in to the Mobile-based peer-to-peer learning prototype.	SUCCEEDED
3	Smallholder dairy producers' registration to the Mobile-based peer-to-peer learning prototype.	SUCCEEDED
4	Smallholder dairy producers log in to the Mobile-based peer-to-peer learning prototype.	SUCCEEDED
5	Smallholder dairy producers complete profiling.	SUCCEEDED
6	Smallholder dairy producers enter the quantity of milk yield per day.	SUCCEEDED
7	Smallholder dairy producers are assigned to their respective production clusters.	SUCCEEDED
8	Smallholder dairy producers can view their progress via the graphs in their dashboard.	SUCCEEDED
9	Smallholder dairy producers can share knowledge regarding farming with their fellows in their production clusters.	SUCCEEDED

4.5.3 System Testing

System tests look at the general functionality of the system as well as how it interacts with other systems. A system test is performed on a fully integrated system to see if the produced system meets requirements (Nidhra & Dondeti, 2012). System testing results from all integrated components successfully passing the integration testing procedure. It is focused on the functional features of source codes that are apparent to the end-user rather than the structural aspects. Two validation questionnaires were used in the system testing process. The first validation questionnaire was for smallholder dairy producers, as shown in Appendix 3, and the second was for extension officers, as shown in Appendix 4. Section B of each questionnaire (in Appendices 3 and 4) are the questions that assess whether the system met users' expectations. The system validation process was conducted to test whether the system meets its requirements; the test results are shown in Table 8.

Table 8: System Testing Results

S/N	Functional Requirements	Test Results
1	The developed solution should be capable of permitting the system admin to register an extension officer.	SUCCEEDED
2	The developed solution should be capable of permitting an extension to login into the system using an email and password.	SUCCEEDED
3	The system should enable the extension officer to edit their information in the database.	SUCCEEDED
4	The system should enable extension officers to view the list of farmers in the same cluster.	SUCCEEDED
5	The developed solution should be capable of permitting smallholder dairy producers to register into the system.	SUCCEEDED
6	The developed solution should be capable of permitting smallholder dairy producers to login into the system using an email and password.	SUCCEEDED
7	The developed solution should be capable of permitting smallholder dairy producers to edit their information in the database.	SUCCEEDED
8	The system should enable smallholder dairy producers to view the list of other producers in the same cluster.	SUCCEEDED
9	The developed solution should be capable of permitting smallholder dairy producers to add a feeding type.	SUCCEEDED
10	The developed solution should be capable of permitting smallholder dairy producers to edit the existing feed type.	SUCCEEDED
11	The developed solution should be capable of permitting smallholder dairy producers to view all lists of feeding types.	SUCCEEDED
12	The developed solution should be capable of permitting the farmers to add feeding frequency by specifying the value of the frequency.	SUCCEEDED
13	The developed solution should be capable of permitting farmers to edit and update the existing feeding frequency value.	SUCCEEDED
14	The developed solution should be capable of permitting farmers to view all lists of feeding frequencies.	SUCCEEDED

S/N	Functional Requirements	Test Results
15	The developed solution should be capable of permitting the farmers to add watering frequency by specifying the value of the frequency.	SUCCEEDED
16	The developed solution should be capable of permitting farmers to edit and update the existing watering frequency value.	SUCCEEDED
17	The developed solution should be capable of permitting farmers to view all lists of watering frequencies.	SUCCEEDED
18	The developed solution should be capable of permitting the farmer to add vaccination frequency by specifying the value of the frequency.	SUCCEEDED
19	The developed solution should be capable of permitting farmers to view all vaccination frequency lists.	SUCCEEDED
20	The developed solution should be capable of permitting farmers to delete existing vaccination frequency.	SUCCEEDED
21	The developed solution should be capable of permitting the farmer to add milking frequency by specifying the value of the frequency.	SUCCEEDED
22	The developed solution should be capable of permitting the farmer to edit and update the existing milking frequency value.	SUCCEEDED
23	The developed solution should be capable of permitting farmers to view all lists of milking frequencies.	SUCCEEDED
24	The developed solution should be capable of permitting the farmer to add visiting frequency by specifying the value of the frequency.	SUCCEEDED
25	The developed solution should be capable of permitting the farmer to edit and update the existing visiting frequency value.	SUCCEEDED
26	The developed solution should be capable of permitting farmers to view all visiting frequency lists.	SUCCEEDED
27	The developed solution should be capable of permitting the farmer to add the number of milking cows by specifying the value.	SUCCEEDED
28	The developed solution should be capable of permitting farmers to edit and update the existing number of milking cows.	SUCCEEDED
29	The developed solution should be capable of permitting the farmer to view all lists of several milking cows.	SUCCEEDED

S/N	Functional Requirements	Test Results
30	The developed solution should be capable of permitting the farmer to add total land for farming by specifying the land size.	SUCCEEDED
31	The developed solution should be capable of permitting the farmer to edit and update the existing range area (land size).	SUCCEEDED
32	The developed solution should be capable of permitting the farmer to add a quantity of milk yield daily by specifying the amount of milk yield in litres.	SUCCEEDED
33	The developed solution should be capable of permitting the farmer to add the quantity of milk sold per week.	SUCCEEDED
34	The developed solution should be capable of permitting the farmer to edit the existing quantity of milk sold.	SUCCEEDED
35	The system should graph several trends of production performance for farmers for personal evaluation based on production.	SUCCEEDED
36	The developed solution should be capable of permitting the system administrator to add a new cluster by specifying the name of the cluster.	SUCCEEDED
37	The developed solution should be capable of permitting the system administrator to view other clusters available in the system.	SUCCEEDED
38	The developed solution should be capable of permitting the system administrator to assign different features to the specified cluster.	SUCCEEDED
39	The developed solution should be capable of permitting farmers to send messages to each other to exchange knowledge within the same cluster or with other members in other clusters.	SUCCEEDED
40	The developed solution should be capable of permitting the farmers to receive notifications suggesting that smallholder dairy producers have higher milk yields.	SUCCEEDED

4.6 System Validation

After software testing on the developer's side, the user acceptance test is performed using the software-testing procedure. Anticipated clients of the generated program carry out acceptance testing. Acceptance testing determines whether the program functions and meets the client's primary business requirements. Privileged users can interact with system functional units to evaluate their accuracy and other performance factors such as speed, ease, and responsiveness.

The validation technique was used on the user side to determine whether the system met the users' expectations.

4.6.1 Stakeholders

There are several reasons stakeholders should be included in their problems and issues to be handled (Jäger & Zakharova, 2014). Smallholder dairy producers and extension officers were two types of stakeholders in this study, and all were fully involved in the study, from feasibility study data collection, and user acceptance testing. In addition, 78 stakeholders were involved in the system validation, where 69 were smallholder dairy producers, and 9 were extension officers.

4.6.2 Validation Methodology

This study adopted the Technology Acceptance Model (TAM) for mobile-based peer-to-peer learning prototype validation. The TAM is founded on the theory of reasoned action, a psychological paradigm that proposes that a person's attitude toward a particular activity influences their behaviour (Michels *et al.,* 2019). The TAM is the dairy industry's most extensively used technology adoption model (Michels *et al.,* 2019). The checklist validation plan (in Section C of the validation questionnaire of both stakeholders) was presented to the stakeholders (Smallholder dairy producers and Extension officers) during the validation process as shown in Appendices 3 and 4 (for Smallholder dairy producers and Extension officers, respectively), the questions. In addition, the Likert scale was used as a validation technique to see if the system met the customer's expectations and, more importantly, if the mobile-based peer-to-peer learning prototype was user-friendly; the test results are shown in Table 9 and Table 10.

Table 9: User Acceptance Testing results for smallholder dairy producers

Validation aspects	Number of respondents					Mean score
	Strong disagree	Disagree	Not sure	Agree	Strong agree	
The user interface is simple and intuitive.	0	0	0	3	66	4.966
The system is more engaging and appealing.	0	0	0	2	67	4.971
The content of the system is simple to understand.	0	0	0	1	68	4.986
Smallholder dairy producers are automatically assigned to a cluster by the system.	0	0	0	0	69	5
The smallholder can use the system to enter their daily milk production.	0	0	0	0	69	5
Smallholder dairy farmers can access daily milk amount records to keep track of their milk yields.	0	0	0	0	69	5
Smallholder dairy farmers can assess their performance by looking at the graph on their dashboard for daily milk yield statistics.	0	0	0	0	69	5
The method allows smallholder dairy farmers to see other cluster members.	0	0	0	0	69	5
The method allows smallholder dairy producers in their clusters to chat and share knowledge and expertise.	0	0	0	0	69	5
If the smallholder dairy producermeets the criteria for a differentcluster, the system can shift them to that cluster after every month.	0	0	0	0	69	5
The proposed tool improves farmer self-assessment, given the increasing milk yields.	0	0	0	2	67	4.971
The technique is beneficial since it is simple to obtain dairy farming extension assistance.	0	0	0	1	68	4.986
I would love to use the system for self-assessment to improve my daily productivity.	0	0	0	0	69	5
I will advise others about the system and encourage them to utilize it for self-assessment and to increase milk yield.	0	0	0	0	69	5

Table 10: User acceptance testing results for extension officers

Validation aspects	Number of respondents					Mean score
	Strong disagree	Disagree	Not sure	Agree	Strong agree	
The user interface is simple and intuitive.	0	0	0	1	8	4.889
The system is more engaging and appealing.	0	0	0	1	8	4.889
The content of the system is simple to understand.	0	0	0	0	9	5
Smallholder dairy producers are automatically assigned to a cluster by the system.	0	0	0	0	9	5
The smallholder can use the system to enter their daily milk production.	0	0	0	0	9	5
Smallholder dairy farmers can access daily milk amount records to keep track of their milk yields.	0	0	0	0	9	5
Smallholder dairy farmers can assess their performance by looking at the graph on their dashboard for daily milk yield statistics.	0	0	0	0	9	5
The method allows smallholder dairy farmers to see other cluster members.	0	0	0	0	9	5
The method allows smallholder dairy producers in their clusters to chat and share knowledge and expertise.	0	0	0	0	9	5
If the smallholder dairy producer meets the criteria for a different cluster, the system can shift them to that cluster after every month.	0	0	0	0	9	5
The proposed tool improves farmer self-assessment, given increasing milk yields.	0	0	0	1	8	4.889
The technique is beneficial since it is simple to obtain dairy farming extension assistance.	0	0	0	0	9	5
I would love to use the system for self-assessment to improve my daily productivity.	0	0	0	0	9	5
I will advise others about the system and encourage them to utilise it for self-assessment and to increase milk yield.	0	0	0	0	9	5

4.7 Discussion

This study obtained various findings that have a variety of practical significance for the dairy sector. They inform smallholder dairy producers and service providers (extension officers). The following are the key findings of this study:

(i) Assigning smallholder dairy producers with comparable traits makes intervention easier

This finding is crucial because it emphasizes the significance of grouping smallholder dairy producers with similar features. Smallholder dairy producers can learn how to grow by joining these groups (clusters), and smallholder dairy producers can share knowledge about the constraints that lead to low milk yield. This finding is in line with the findings of a study conducted by (Goswami *et al.*, 2014), which revealed that smallholder dairy producers with comparable features could share knowledge about the specific restraining causes in various farm types. This indicates that the growth of smallholder dairy producers may be examined more simply when they are in homogenous groups.

(ii) Peer-to-peer learning makes it easier for smallholder dairy producers to share their knowledge and experiences

With this finding, smallholder dairy producers can share their farming knowledge and experience by chatting inside their clusters to increase milk yield, which aligns with the results (Nyambo, 2020). Peer interactions have good effects, such as gaining experience and expanding knowledge. Moreover, Tran (2013) explains that learning occurs in a social environment where learners acquire knowledge, norms, skills, tactics, and beliefs through observing others. Peer-to-peer learning also helps bridge the gap between small-scale dairy farmers and extension officers (Thakur & Chander, 2018).

(iii) Livestock extension services that are delivered on time

This finding emphasizes that livestock extension and consulting services are important in dairy farming. They assist smallholder dairy farmers with their challenges (production and management issues) by enhancing their knowledge and farm management abilities, resulting in higher milk yield, which corresponds to the findings of a study (Ahikiriza *et al.*, 2021). In this scenario, timely extension services are more critical to increasing milk yield. Smallholder dairy producers obtain timely extension assistance by involving extension personnel in peer-to-peer groups (clusters).

Smallholder dairy producers are strongly urged to join these clusters to boost milk yield, which is the study's major purpose. Smallholder dairy producers can increase milk yields by using social learning and peer-to-peer interaction via clusters and receiving timely extension assistance from extension officers.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Smallholder dairy producers have tried a variety of strategies to boost milk output, but they all require a combination of heuristics, time, and money (Nyambo *et al.*, 2019). Farmers are locked in failure cycles and unsuccessful attempts because of insufficient and unavailable extension services (all agricultural help from extension workers, such as feeding techniques and health services). As a result, their willingness to continue farming investments was damaged (Nyambo *et al.*, 2019). The divide between farmers and extension officers is bridged via peer-to-peer knowledge sharing (Thakur & Chander, 2018). Therefore, this study aimed to develop a peer-to-peer learning prototype for smallholder dairy producers to increase milk yield.

Smallholder dairy producers benefit from the peer-to-peer learning prototype because they can exchange farming expertise and experience while receiving prompt assistance from extension workers. Furthermore, a rule-based engine automatically assigned smallholder dairy producers with comparable farming characteristics to their respective clusters. The issue of a lack of extension officers was addressed in this case. In addition, smallholder dairy producers would no longer have to rely on trial and error to increase milk output because they could share their farming procedures knowledge and experience with their colleagues.

Based on a quantitative analysis done using R programming language, it shows that Cluster 1 is the best performer, followed by Cluster 2, then Cluster 6. On the other hand, where low-performing clusters were Cluster 5, followed by Cluster 3, then Cluster 5 (Fig. 9). Therefore, from the results, the best-performing smallholder dairy producers were assigned to Cluster 1, and the following good-performing smallholder dairy producers were assigned to Cluster 2, followed by others in Cluster 6. In addition, the low-performing smallholder dairy producers were assigned to Cluster 5, followed by Cluster 3 and Cluster 4 as per cluster performance.

The first specific objective was achieved through the rule-based engine of the mobile-based peer-to-peer learning prototype. The prototype automatically assigned smallholder dairy producers to their production clusters and allowed them to share knowledge and experience within their clusters through chatting. Moreover, using graphs of their daily milk yield records in their dashboard, smallholder dairy producers can evaluate themselves in terms of milk yield.

Smallholder dairy producers were the focus of this peer-to-peer learning prototype. The second objective was achieved by developing a peer-to-peer learning prototype using scrum agile software development methodology and various software as discussed in section 3.7 of Chapter 3. The smallholder dairy producers were placed in their belonging clusters using the rule-based engine for knowledge and experience sharing regarding farming. A rules engine is a system that performs a set of actions based on specific conditions which can be configured during runtime (Gefroh, 2020). This study used the milk peak value as a rule's engine. In addition, smallholder dairy producers who adopted farming techniques from their peers and upgraded in milk production were auto-relocated to the other cluster based on their current production status.

The third specific objective was achieved when the peer-to-peer learning prototype went through three steps of testing: unit testing, integration testing, and system testing, before the validation process. Finally, user acceptance testing was validated, and the Technology Acceptance Model (TAM) was used to validate a peer-to-peer learning prototype. The validation results highlight the importance of smallholder dairy producers employing the peer-to-peer learning prototype to boost milk yields. In addition, extension officers provide timely assistance to smallholder dairy producers.

Moreover, smallholder dairy producers managed to get support from registered extension officers' using the developed peer-to-peer learning prototype whenever needed; hence a huge contribution to improving milk yield and the shortage of extension workers are solved.

5.2 Recommendations

5.2.1 Implications to Policy-Makers

The study recommends policymakers formulate a dairy farming policy that promotes the usage of a mobile-based peer-to-peer learning prototype for enhancing milk production among smallholder dairy producers. In addition, to propose to the government the allotment of extension officers for quick action whenever smallholder dairy producers require physical extension assistance. Furthermore, they provided the necessary support to researchers striving to solve the issues faced by smallholder dairy producers to improve productivity, boosting the country's economy.

Through its local government officers, the government should hold monthly meetings with smallholder dairy producers to share milk production reports to motivate and encourage non-system users to join the system and gain more exposure because smallholder dairy producers come from various clusters. In addition, extension officers should host virtual meetings with the cluster members to deliver more information to smallholder dairy farmers to supplement their knowledge and experience in farming with the primary goal of increasing milk yields. They can choose to have it once a month because smallholder dairy farmers evaluate their progress every month. If they have improved and can move to another cluster, the system re-locates the smallholder dairy farmer to their appropriate cluster based on their milk peak value.

5.2.2 Implications to Practitioners

The peer-to-peer learning prototype assists smallholder dairy producers in sharing information and experience about farming to boost milk yield. The practitioners are smallholder dairy producers and extension officers. Chatting inside their clusters facilitates knowledge transfer. Moreover, extension officers can provide timely services to smallholder dairy farmers and serve many smallholders dairy farmers in a short period. Furthermore, the issue of a shortage of extension officers is addressed, as there will be artificial extension officers recruited from farmers with strong milk production records.

5.2.3 Future Research

The data were limited because they were undertaken in only one Tanzania region called Arusha. Therefore, further research is needed to cover all regions in Tanzania in a larger samplesize. Future research can also add more features to improve the developed peer-to-peer learning prototype. The first issue is integrating the peer-to-peer with the market by including companies that process milk for other milk products, like yoghurt since marketing is a critical component of the dairy supply chain (Ibrahim *et al.*, 2018). In addition, a crucial motivator for milk producers is the availability of nearby markets for milk and dairy products (Ibrahim *et al.*, 2018). Moreover, other researchers should think about creating a web-based peer-to-peer learning prototype to make the process of putting the software on their phones easier. As a result, corporations and other dairy practitioners can use browsers to access the service(s).

REFERENCES

Aduna, T. F., & Ayalew, W. (2019). Assessment of Dairy cattle management in Gurage Zone, Southern Nations Nationalities and Peoples Region, Ethiopia. *International Journal of Research Studies in Agricultural Sciences*, *5*(4), 1-10.

Ahikiriza, E., Wesana, J., Gellynck, X., Van Huylenbroeck, G., & Lauwers, L. (2021). Context specificity and time dependency in classifying sub-Saharan Africa dairy cattle farmers for targeted extension farm advice: The case of Uganda. *Agriculture*, *11*(9), 836.

Akpan, V. I., Igwe, U. A., Mpamah, I. B. I., & Okoro, C. O. (2020). Social constructivism: Implications on teaching and learning. *British Journal of Education, 8*(8), 49-56.

Ali, A., Mustafa, M., Bilal, M., Muhammad, G., Lateef, M., & Ullah, S. (2015). Effect of watering frequency on feed intake, milk production and composition in Sahiwal cattle during summer. *Journal of Animal and Plant Sciences*, *25*(1), 19-22.

Alonso, S., Toye, P. G., Msalya, G., Grace, D., & Unger, F. (2014). Smallholder dairy farming in Tanzania: Farming practices, animal health and public health challenges and opportunities. *The 6th All Africa Conference on Animal Agriculture,* 429-731.

Atuhaire, A. M., Mugerwa, S., Kabirizi, J., Okello, S., & Kabi, F. (2014). Production Characteristics of Smallholder Dairy Farming in the Lake Victoria Agro-ecological Zone Uganda. *Frontiers in Science*, *4*(1), 12-19.

Baumüller, H. (2018). The little we know: An exploratory literature review on the Utility of mobile phone-enabled Services for smallholder farmers. *Journal of International Development*, *30*(1), 134-154.

Beimel, D., & Kedmi-Shahar, E. (2019). Improving the identification of functional system requirements when novice analysts create use case diagrams: The benefits of applying conceptual mental models. *Requirements Engineering*, *24*(4), 483-502.

Bingi, S., & Tondel, F. (2015). Recent developments in the dairy sector in Eastern Africa. *Briefing note of the European Centre for Development Policy Management*, *78*, 19.

Brett, C. I. (2019). *A new way to boost smallholder dairy productivity in Tanzania*. https://blogs.worldbank.org/voices/new-way-boost-smallholder-dairy-productivity-tanzania.

Brotzman, R., Cook, N., Nordlund, K., Bennett, T., Rivas, A. G., & Döpfer, D. (2015). Cluster analysis of Dairy Herd Improvement data to discover trends in performance characteristics in large Upper Midwest dairy herds. *Journal of Dairy Science*, *98*(5), 3059-3070.

Chiumia, D., Gondwe, T. N., Banda, L. J., Sivaselvam, S., Ulbrich, S. E., & Chagunda, M. G. (2020). Enhancing knowledge exchange and performance recording through the use of short messaging service in smallholder dairy farming systems in Malawi. *Cogent Food & Agriculture*, *6*(1), 1801214.

Crawford, L. M. (2019). Conceptual and theoretical frameworks in research. *Research Design and Methods: An Applied Guide for the Scholar-Practitioner*, 35-48.

Erickson, P. S., & Kalscheur, K. F. (2020). Nutrition and feeding of dairy cattle. *Animal Agriculture*, 157-180

Faysse, N., Sraïri, M. T., & Errahj, M. (2012). Local farmers' organizations: A space for peer-to-peer learning: The case of milk collection cooperatives in Morocco. *The Journal of Agricultural Education and Extension*, *18*(3), 285-299.

Gefroh, J. (2020). *How to Design Software Rules Engines*. https://medium.com/swlh/how-to-design-software-rules-engines-adbb098b2d73.

Goswami, R., Chatterjee, S., & Prasad, B. (2014). Farm types and their economic characterization in complex agroecosystems for informed extension intervention: A study from coastal West Bengal, India. *Agricultural and Food Economics*, *2*(1), 5.

Guadu, T., & Abebaw, M. (2016). Challenges, opportunities and prospects of dairy farming in Ethiopia: A review. *World Journal of Dairy & Food Sciences*, *11*(1), 01-09.

Guru99. (2022). *Functional Vs. Non-Functional Requirements: Differences*. Functional Vs. Non-Functional Requirements: Differences.

Humer, E., Petri, R., Aschenbach, J., Bradford, B., Penner, G., Tafaj, M., Südekum, K.-H., & Zebeli, Q. (2018). Invited review: Practical feeding management recommendations to mitigate the risk of subacute ruminal acidosis in dairy cattle. *Journal of Dairy Science*, *101*(2), 872-888.

Ibrahim, A., Akyoo, A., & Kanuya, N. (2018). Analysis of marketing performance of the dairy value chain in Tanga City, Tanzania. *Tanzania Journal of Agricultural Sciences*, *17*(2).

Ibrahim, R. (2010). Formalization of the data flow diagram rules for consistency check. *arXiv Preprint arXiv:1011.0278*.

Jaakkola, H., & Thalheim, B. (2011). Architecture-driven modelling methodologies. In *Information Modelling and Knowledge Bases XXII*, 97-116.

Jäger, T., & Zakharova, A. (2014). Stakeholder participation to improve societal acceptance of mega projects.: A case study of the forum for the coal-power plant "Datteln 4" project. Master Thesis. https://www.diva-portal.org/smash/record.jsf?pid=diva2:691192.

Kamath, V. D., Meher, A., Vidhya, V., & Deepthi, S. (2018). An Android-based Mobile Application for Career Guidance. In *2018 Second International Conference on Inventive Communication and Computational Technologies*, 854-860.

Khaskheli, A. (2020). Influence of dietary manipulations and milking frequency on the production of dairy cows. *Online Journal of Animal and Feed Research*, *10*(4), 115-119.

Krell, N., Giroux, S., Guido, Z., Hannah, C., Lopus, S., Caylor, K., & Evans, T. (2020). Smallholder farmers' use of mobile phone services in central Kenya. *Climate and Development*, 1-13.

Kyaruzi, J. J., Yonah, Z. O., & Swai, H. S. (2019). Mobile application development framework to support farming as a business via benchmarking: The case of Tanzania. *International Journal of Advanced Computer Research*, *9*(45), 365-378.

Lai, P. C. (2017). The literature review of technology adoption models and theories for the novelty technology. *Journal of Information Systems and Technology Management*, *14*, 21-38.

Lijalem, T., Asefa, A., Sharo, A., & Wollaita, E. (2015). Dairy cattle production at smallholder level in Sidama zone selected districts, southern Ethiopia. *Food Science and Quality Management*, 2224-6088.

Lowder, S. K., Skoet, J., & Raney, T. (2016). The number, size, and distribution of farms, smallholder farms, and family farms worldwide. *World Development*, *87*, 16-29.

Lynch, M. (2016). *Social Constructivism in Education*. https://www.theedadvocate.org/social-constructivism-in-education.

Makau, D., VanLeeuwen, J., Gitau, G., Muraya, J., McKenna, S., Walton, C., & Wichtel, J. (2018). Effectiveness of using cellphone technology as a dairy management training tool for smallholder dairy farms in Kenya. *Livestock Research for Rural Development, 30*(11), 1-11.

Marwa, M. E. (2019). Impact of ICT-based extension services on Dairy Production in Kenya: A case of iCow service.

Marwa, M. E., Mburu, J., Elizaphan, R., Oburu, J., Mwai, O., & Kahumbu, S. (2020). Impact of ICT-based extension services on dairy production and household Welfare: The case of iCow service in Kenya. *Journal of Agriculture Science*, *12*(3), 1-12.

Michels, M., Bonke, V., & Musshoff, O. (2019). Understanding the adoption of smartphone apps in dairy herd management. *Journal of Dairy Science*, *102*(10), 9422-9434.

Mudiwa, B. The Influence of Groups and Group Leadership on Smallholder Beef Enterprise Performance: A Case of Chipinge District in Zimbabwe.

Mudiwa, B. (2017). The Influence of Groups and Group Leadership on Smallholder Beef Enterprise Performance: A Case of Chipinge District in Zimbabwe.

Naeem, T. (2021). *What is Database Design?* https://www.astera.com/type/blog/all-you-need-to-know-about-database-design.

Ng'ang'a, F. N. (2013). *An evaluation of access to and use of Agricultural information by extension service officers: A case study of Makueni County, Kenya University of Nairobi.*

Nidhra, S., & Dondeti, J. (2012). Black box and white box testing techniques-a literature review. *International Journal of Embedded Systems and Applications*, *2*(2), 29-50.

Nyambo, D. (2020). *Use of agent–based models in characterizing farm types and evolvement in smallholder dairy systems* (Doctoral dissertation).

Nyambo, D. G., Luhanga, E. T., Yonah, Z. O., & Mujibi, F. D. (2019). Application of multiple unsupervised models to validate clusters' robustness in characterizing smallholder dairy farmers. *The Scientific World Journal*, *2019*.

Nyambo, D. G., Luhanga, E. T., Yonah, Z. O., Mujibi, F. D., & Clemen, T. (2020). Leveraging peer-to-peer farmer learning to facilitate better strategies in smallholder dairy husbandry. *Adaptive Behavior*, 1059712320971369.

O'Dea, S. (2021). Share of mobile operating systems in Africa 2018-2021.

Omulo, G., & Kumeh, E. M. (2020). Farmer-to-farmer digital network as a strategy to strengthen agricultural performance in Kenya: A research note on 'Wefarm'platform. *Technological Forecasting and Social Change*, *158*, 120120.

Patii, U., Saxena, P., & Sidnal, N. (2017, August). Peer-to-peer knowledge sharing platform for farmers with auto-recommendation feature. *2017 International Conference on Smart Technologies for Smart Nation*, 879-884.

Rumjaun, A., & Narod, F. (2020). Social Learning Theory Albert Bandura. *Science Education in Theory and Practice: An Introductory Guide to Learning Theory*, 85-99.

Sennuga, S. O., Conway, J. S., & Sennuga, M. A. (2020). Impact of information and communication technologies (ICTS) on agricultural productivity among smallholder farmers: Evidence from Sub-Saharan African communities. *International Journal of Agricultural Extension and Rural Development Studies*, *7*(1), 27-43.

SmartDraw, L. (2022). *Use Case Diagram*. https://www.smartdraw.com/use-case-diagram.

Swai, E., Mollel, P., & Malima, A. (2014). Some factors associated with poor reproductive performance in smallholder dairy cows: The case of Hai and Meru districts, Northern Tanzania. *Livestock Research for Rural Development*, *26*(6), 1-2.

Taneja, M., Jalodia, N., Byabazaire, J., Davy, A., & Olariu, C. (2019). SmartHerd management: A microservices-based fog computing–assisted IoT platform towards data-driven smart dairy farming. *Software: Practice and Experience*, *49*(7), 1055-1078.

Thakur, D., & Chander, M. (2018). Use of social media in agricultural extension: Some evidence from India. *International Journal of Science, Environment and Technology*, *7*(4), 1334-1346.

Thiam, S. M. b., & Matofari, J. W. (2018). The Role of Information and Communication Sharing Pathway in Improving Peri-Urban Dairy System of Bamako, Mali. *American Journal of Science, Engineering and Technology*, *3*(1), 21.

Tran, V. D. (2013). Theoretical Perspectives Underlying the Application of Cooperative Learning in Classrooms. *International Journal of Higher Education*, *2*(4), 101-115.

Varpio, L., Paradis, E., Uijtdehaage, S., & Young, M. (2020). The distinctions between theory, theoretical framework, and conceptual framework. *Academic Medicine*, *95*(7), 989-994.

Velmurugan, S., Gan, J. M., Rathod, K. S., Khambata, R. S., Ghosh, S. M., Hartley, A., Van Eijl, S., Sagi-Kiss, V., Chowdhury, T. A., & Curtis, M. (2016). Dietary nitrate improves vascular function in patients with hypercholesterolemia: a randomized, double-blind, placebo-controlled study. *The American Journal of Clinical Nutrition*, *103*(1), 25-38.

Venkatesh, V. (2022). Adoption and use of AI tools: a research agenda grounded in UTAUT. *Annals of Operations Research*, 1-12.

Venkatesh, V., Thong, J. Y., & Xu, X. (2012). Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. *Management Information Systems Quarterly*, 157-178.

Verma, N., Kansal, S., & Malvi, H. (2018). Development of native mobile application using Android studio for cabs and some glimpse of cross-platform apps. *InternationalJournal of Applied Engineering Research*, *13*(16), 12527-12530.

Wang, J., Li, X., Wang, P., Liu, Q., Deng, Z., & Wang, J. (2022). Research Trend of the Unified Theory of Acceptance and Use of Technology Theory: A Bibliometric Analysis. *Sustainability*, *14*(1), 10.

Waziri, M. D., & Uliwa, P. (2020). Supply and Commercial Viability of Forage in Tanzania. *American Scientific Research Journal for Engineering, Technology, and Sciences*, *66*(1), 145-156.

Yan, B., & Chen, G. (2011). AppJoy: Personalized mobile application discovery. *Proceedings of the 9th International Conference on Mobile Systems, applications, and Services.*

APPENDICES

Appendix 1: Questionnaire for Data Collection for Smallholder Dairy Producers

"Mobile-based Peer-to-Peer Learning Prototype for Smallholder Dairy Producers"

Smallholder dairy producers will use the system to increase milk yield by sharing experiences regarding farming issues and getting on-time service, especially advice from extension officers who will be in the same system.

This survey questionnaire aims to collect Smallholder dairy producers' personal information regarding farming practices. This system will help smallholder dairy producers exchange knowledge about farming methods and get advice from extension workers.

Section A: Demographic Information

Are you ready to participate in filling out this survey questionnaire?

Yes

No

Where do you live? ……………………….

What is your gender?

Male

Female

What is your education level?

Primary

Secondary

Certificate

Diploma and Above

Informal Education

Section B: Questions about Production Activities

How many milking cows do you have?

……………………………………………….

How much area for livestock keeping do you have?

………………………………………………

How many times do you feed your cows per day?

Once

Twice

Trice

More than Trice

What kind of food do you use to feed your cows?

Roughages

Roughages and Concentrate

Roughages and Supplements

Both

How many times do you give water to your cows?

……………………………………………………………………………………………

How many times do you milk your cows per day?

Once

Twice

Trice

More than Trice

What means of communication do you use to meet with extension officers?

……………………………………………………………………………………………

Is that mechanism friendly, do you meet with the extension officers on time?

Yes

No

How much per cent does the mechanism score?

Above 50%

Below 50%

Section C: Questions about how to improve the existing system

What should be done to improve the mechanism used to meet with the extension officers time

……………………………………………………………………………………………………

…………………………………………………………………………………………………

What if we introduce a system connecting dairy farmers to share knowledge and experience concerning farming? Will it be helpful?

Yes

No

Will it be beneficial if a system is put in place that allows extension officers to provide help whenever needed?

Yes

No

What per cent do you think the system will be helpful?

Below 50%

Above 50%

Thank you so much for your precious time, we value it.

Appendix 2: Questionnaire for Data Collection for Extension Officers

"Mobile-based Peer-to-Peer Learning Prototype for Smallholder Dairy Producers"

Smallholder dairy producers will use the system to increase milk yield by sharing experiences regarding farming issues and getting on-time service, especially advice from extension officers who will be in the same system.

This survey questionnaire aims to collect extension officers' personal information regarding /her education and provide a shortlist of best practices that are key to improving milk yield. In addition, this system will help smallholder dairy producers exchange knowledge about farming methods and get advice from extension workers.

Section A: Demographic Information

Are you ready to participate in filling out this survey questionnaire?

Yes

No

Where do you live (residence)? ……………………….

What is your gender?

Male

Female

What is your education level?

Certificate

Diploma and Above

Area of specialization

………………………………………………………………………………………………

Section B: Questions about farming techniques and their impact on increasing milk yield

What is the status of the farmer concerning yielding who feeds their cows twice a day?

Very good

Average

Poor

What is the status of the farmer concerning yielding who feeds their cows twice a day?

Very good

Average

Bad

What is the status of the farmer concerning yielding who feeds their cows twice a day?

Very good

Average

Poor

What is the status of the farmer concerning yielding whose milking frequency of their cows is once a day?

Very good

Average

Poor

What is the status of the farmer concerning yielding whose milking frequency of their cows is twice a day?

Very good

Average

Poor

What is the status of the farmer concerning yielding whose milking frequency of their cows is trice a day?

Very good

Average

Poor

How much watering frequency does the cow need per day to increase milk-yielding? Mention the frequency with its status (*e.g. More than 3 times; very good*).

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
………………

What are the strong characteristics of dairy farming to increase milk yield?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
………………

Section C: Questions about the existing system

How many dairy farmers are served by a single extension officer daily?

………………………………………………………………………………………………

How many times does the farmer need extension officers to visit per month?

………………………………………………………………………………………………

Which system (existing) do extension officers meet dairy farmers use? ………………………………………………………………………………………………

Is the existing system user-friend? How many farmers can an extension officer meet per day

……..……………………………………………………………………………………….

Section D: How to improve the existing

Is the existing system user-friend?

Yes

No

What should be done to reach many dairy farmers at once?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

What if we introduce a system connecting dairy farmers to share knowledge and experience concerning farming? Will it be helpful?

Yes

No

Will a system that involves extension officials assisting whenever needed be beneficial?

Yes

No

What per cent do you think the system will be helpful?

Below 50%

Above 50%

What is your opinion regarding this system?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Thank you for your valuable time!

Appendix 3: System Validation Questionnaire for Smallholder Dairy Producers

User acceptance test for the mobile-based peer-to-peer learning prototype for smallholder dairy producers.

Questions to Smallholder Dairy Producers

Smallholder dairy producers will use the system to boost milk yields by sharing farming knowledge and receiving timely assistance, including advice from extension officers who will be in the same system. This survey questionnaire assesses smallholder dairy producers' acceptability of a mobile-based peer-to-peer learning prototype. This user-acceptance test aids in determining the accessibility of the mobile-based peer-to-peer learning prototype and its importance.

Section A: Demographic Information

Please provide accurate information

Are you ready to participate in filling out this questionnaire?

Yes ☐

No ☐

Where do you live?

………………………

Gander

Female ☐

Male ☐

Education level

Primary

Secondary

Certificate

Diploma and Above

Informal Education

Section B: Questions to evaluate the system functionality

Please put a ***(√)*** *if the requirement is met and* ***(x)*** *if the requirement is not met*

Does the system allow smallholder dairy producers to register into the system using their first name, last name, email, phone number, and residential address?

Does the system allow smallholder dairy producers to log in using an email and password?

Does the system automatically allocate smallholder dairy producers to their respective clusters after completing the registration?

Does the system enable smallholder dairy producers to view the list of other producers in the same cluster?

Does the system allow smallholder dairy producers to add a feed type?

Does the system allow smallholder dairy producers to view all lists of feed types?

Does the system allow smallholder dairy producers to add feed frequency by specifying the value of the frequency?

Does the system allow smallholder dairy producers to view all lists of feeding frequencies?

Does the system allow the smallholder dairy producers to add watering frequency by specifying the value of the frequency?

Does the system allow the smallholder dairy producers to view all lists of watering frequencies?

Does the system allow the smallholder dairy producers to add vaccination frequency by specifying the value of the frequency? ☐

Does the system allow the smallholder dairy producers to view all lists of vaccination frequency? ☐

Does the system allow the smallholder dairy producers to add milking frequency by specifying the value of the frequency? ☐

Does the system allow the smallholder dairy producers to view all lists of milking frequencies? ☐

Does the system allow the smallholder dairy producers to add visiting frequency by specifying the value of the frequency? ☐

Does the system allow the smallholder dairy producers to view all visiting frequency lists? ☐

Does the system allow the smallholder dairy producers to add the number of milking cows by specifying the value? ☐

Does the system allow the smallholder dairy producers to view all lists of several milking cows? ☐

Does the system allow the smallholder dairy producers to add total land for farming by specifying the value? ☐

Does the system allow smallholder dairy producers to view all lists of farming areas? ☐

Does the system allow the smallholder dairy producers to add a quantity of milk yield by specifying a value? ☐

Does the system allow the smallholder dairy producers to add the quantity of milk sold? ☐

Can smallholder dairy producers evaluate their performance by viewing the graph for daily milk yield records in their dashboards? ☐

Section C: System functionality ranking and Recommendation

Please put (√) to one of your choices based on the scale given to rate the system (E.g., Strong agree √)

Validation aspects	Number of respondents					Mean score
	Strong disagree	**Disagree**	**Not sure**	**Agree**	**Strong agree**	
The user interface is simple and intuitive.						
The system is more engaging and appealing.						
The content of the system is simple to understand.						
Smallholder dairy producers are automatically assigned to a cluster by the system.						
The smallholder can use the system to enter their daily milk production.						
Smallholder dairy farmers can access daily milk amount records to keep track of their milk yields.						
Smallholder dairy farmers can assess their performance by looking at the graph on their dashboard for daily milk yield statistics.						
The method allows smallholder dairy farmers to see other cluster members.						
The method allows smallholder dairy producers in their clusters to chat and share knowledge and expertise.						
If the smallholder dairy producermeets the criteria for a differentcluster, the system can shift them to that cluster after every month.						
The proposed tool improves farmer self-assessment, given the increasing milk yields.						
The technique is beneficial since it is simple to obtain dairy farming extension assistance.						
I would love to use the system for self-assessment to improve my daily productivity.						
I will advise others about the system and encourage them to utilise it for self-assessment and to increase milk yield.						

Thank you for your valuable time!

Appendix 4: System Validation Questionnaire for Extension Officers

User acceptance test for the mobile-based peer-to-peer learning prototype for smallholder dairy producers.

Questions to Extension officers

Smallholder dairy producers will use the system to boost milk yields by sharing farming knowledge and receiving timely assistance, including advice from extension officers who will be in the same system. This survey questionnaire assesses smallholder dairy producers' acceptability of a mobile-based peer-to-peer learning prototype. This user-acceptance test aids in determining the accessibility of the mobile-based peer-to-peer learning prototype and its importance.

Section A: Demographic Information

Are you ready to participate in filling out this survey questionnaire?

Yes ☐

No ☐

Where do you live (residence)?

……………………….

Gander

Female ☐

Male ☐

Education level

Certificate ☐

Diploma and Above ☐

Area of specialization

……………………………………………………………………………….…

Section B: Functional System Requirements

Please put a (√) if the requirement is met and (X) if the requirement is not met.

The developed solution should be capable of permitting the system admin to register an extension officer. Extension officers registered in the system by providing the following information Officer-ID, first name, last name, email, and designation. ☐

The developed solution should be capable of permitting an extension officer to login into the system using an email and password. ☐

The system should enable the extension officer to edit their information in the database. The information to be edited is the username and password when one wishes to change them. ☐

The system should enable extension officers to view the list of farmers in the same cluster. ☐

The system should enable smallholder dairy producers to view the list of other producers in the same cluster. ☐

The developed solution should be capable of permitting smallholder dairy producers to add a feeding type. ☐

The developed solution should be capable of permitting smallholder dairy producers to view all lists of feeding types. ☐

The developed solution should be capable of permitting the smallholder dairy producers to add feeding frequency by specifying the value of the frequency. ☐

The developed solution should be capable of permitting smallholder dairy producers to view all lists of feeding frequencies. ☐

The developed solution should be capable of permitting smallholder dairy producers to add watering frequency by specifying the value of the frequency. ☐

The developed solution should be capable of permitting smallholder dairy producers to view all lists of watering frequencies. ☐

The developed solution should be capable of permitting smallholder dairy producers to add vaccination frequency by specifying the value of the frequency. ☐

The developed solution should be capable of permitting smallholder dairy producers to view all lists of vaccination frequencies. ☐

The developed solution should be capable of permitting smallholder dairy producers to add milking frequency by specifying the value of the frequency. ☐

The developed solution should be capable of permitting smallholder dairy producers to view all lists of milking frequencies. ☐

The developed solution should be capable of permitting the smallholder dairy producers to add visiting frequency by specifying the value of the frequency. ☐

The developed solution should be capable of permitting smallholder dairy producers to view all visiting frequency lists. ☐

The developed solution should be capable of permitting smallholder dairy producers to add the number of milking cows by specifying the value. ☐

The developed solution should be capable of permitting smallholder dairy producers to view all lists of several milking cows. ☐

The developed solution should be capable of permitting the smallholder dairy producers to add total land for farming by specifying the value. ☐

The developed solution should be capable of permitting smallholder dairy producers to view all lists of farming areas. ☐

The developed solution should be capable of permitting smallholder dairy producers to add a quantity of milk yield by specifying a value. ☐

The developed solution should be capable of permitting the smallholder dairy producers to add the quantity of milk sold. ☐

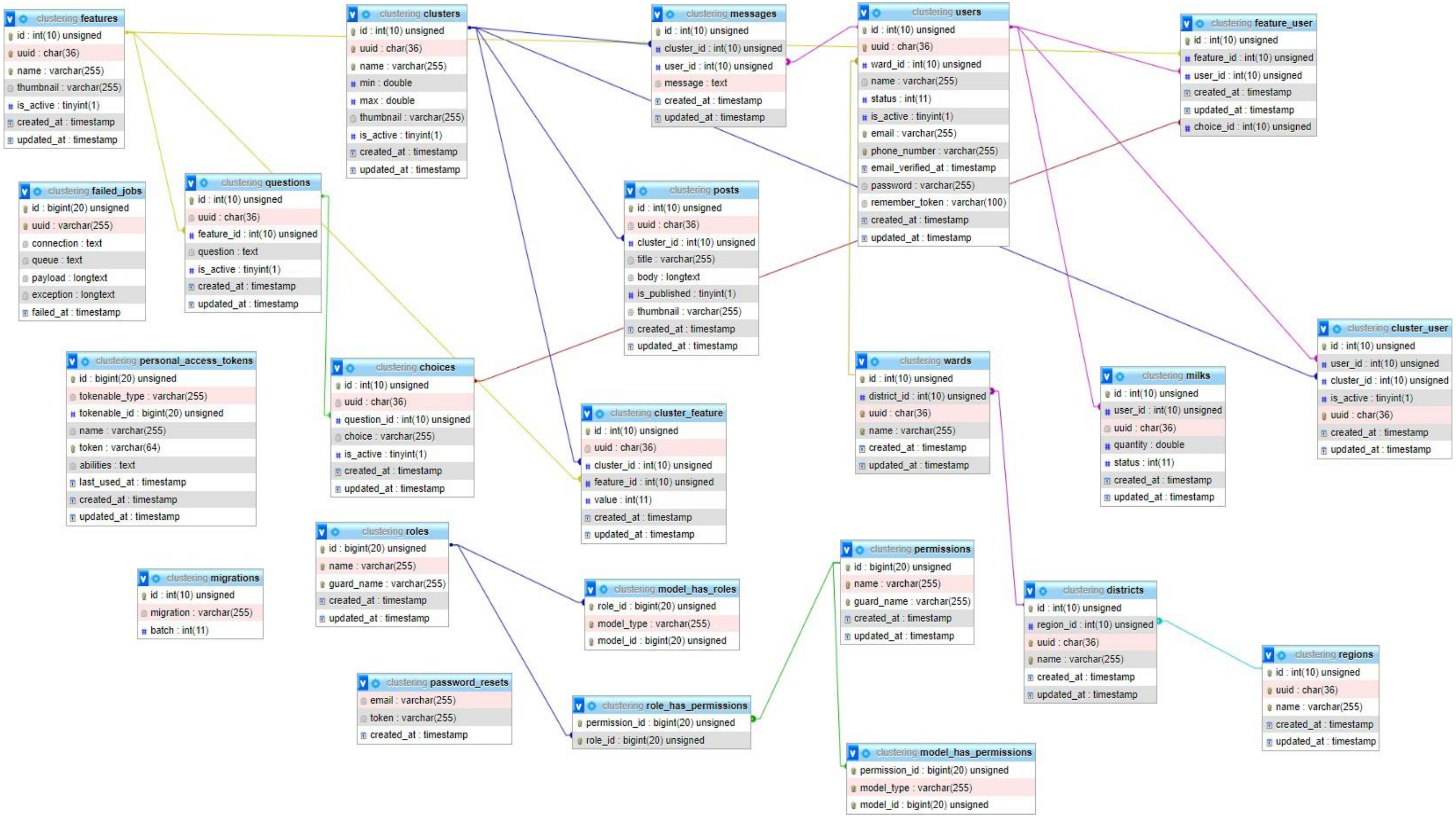
Section C: System functionality ranking and Recommendation

Please put (√) to one of your choices based on the scale given (E.g. Strong agree √)

Validation aspects	Number of respondents					Mean score
	Strong disagree	Disagree	Not sure	Agree	Strong agree	
The user interface is simple and intuitive.						
The system is more engaging and appealing.						
The content of the system is simple to understand.						
Smallholder dairy producers are automatically assigned to a cluster by the system using the rule-based engine.						
The smallholder can use the system to enter their daily milk production.						
Smallholder dairy farmers can access daily milk amount records to keep track of their milk yields.						
Smallholder dairy farmers can assess their performance by looking at the graph on their dashboard for daily milk yield statistics.						
The method allows smallholder dairy farmers to see other cluster members.						
The method allows smallholder dairy producers in their clusters to chat and share knowledge and expertise.						
If the smallholder dairy producer meets the criteria for a different cluster, the system can shift them to that cluster after every month.						
The technology is effective at enabling self-assessment for dairy producers.						
The technique is beneficial since it is simple to obtain dairy farming extension assistance.						
I will advise dairy farmers about the method and encourage them to utilise it for self-assessment and to increase milk yield.						

Thank you for your valuable time!.

Appendix 5: Database Design of The Mobile-Based Peer-To-Peer Learning Prototype



RESEARCH OUTPUTS

(i) Journal Paper

Mavura, F., Pandhare, S. M., Mkoba, E., & Nyambo, D. G. (2022). Rule-Based Engine for Automatic Allocation of Smallholder Dairy Producers in Preidentified Production Clusters. *The Scientific World Journal*, *2022*, 1-14. https://doi.org/10.1155/2022/6944151.

(ii) Poster Presentation

Appendix 6: Poster Presentation

MOBILE-BASED PEER-TO-PEER LEARNING PROTOTYPE FOR SMALLHOLDER DAIRY PRODUCERS

Fatuma Mavura[1] Sanket M. Pandhare[1] Dr. Elizabeth Mkoba[1] Dr. Devotha G. Nyambo[1]

1 Nelson Mandela African Institution of Science and Technology (NM-AIST), P.O. Box 447, Arusha, Tanzania.

Emails: mavuraf@nm-aist.ac.tz; Elizabeth.mkoba@nm-aist.ac.tz; sanket.pandhare@nm-aist.ac.tz; devotha.nyambo@nm-aist.ac.tz

Introduction

East Africa is in the first position for milk production in Africa; it contributes about 68% of the milk produced in Africa (Bingi & Tondel, 2015). Smallholder dairy producers are challenged to achieve appropriate milk yields (Alonso .et al, 2014). East African countries suffer similar problems such as low dairy productivity and deficient milk quality. Tanzania's livestock productivity is low, as it is in other underdeveloped nations (Waziri & Uliwa, 2020). Smallholder farmers make up the majority of Tanzania's dairy industry, which struggles for a number of reasons, including the fact that 97% of the country's dairy cattle are low-yield breeds, poor management techniques are common, and there are seasonal variations in forage and feed availability. This prevents a lot of smallholder farmers from getting access to veterinarian or extension services at a reasonable price. This study developed a user-friendly mobile-based peer-to-peer learning prototype that smallholder dairy farmers may use to share their farming expertise and experience of increasing milk yield.

Materials and Methods

The scrum method has additional advantages over other Agile development methods since it breaks the project down into manageable subtasks and allocates time for completing each subtask. In this instance, it ensures that each task is completed by its due time in orderto meet the deadline. These processes were applied in this study. Through the milestones reached at the conclusion of each subtask. As a result, it made it possible for the authors to get together and talk about all the milestones they had reached.

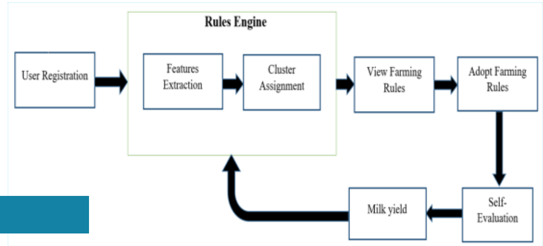


Figure 1: Conceptual framework

Results

Cluster performance vs Specific production feature.

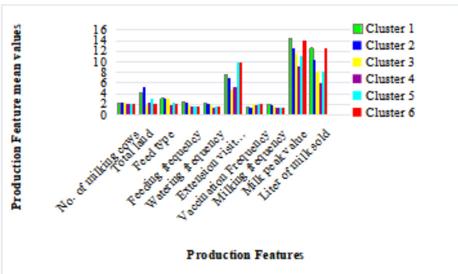


Figure 2: Cluster performance vs Specific production feature.

Overall cluster performance vs production features.

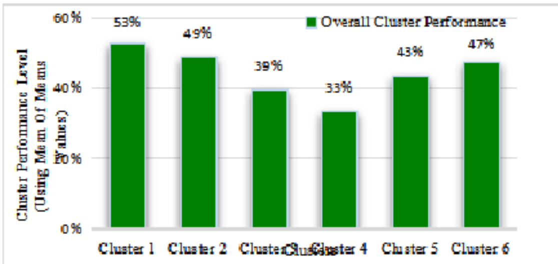


Figure 3: Overall cluster performance vs production features.

Conclusion

Smallholder dairy producers managed to get support from registered extension officers' using the developed mobile-based peer-to-peer learning prototype whenever needed, hence a huge contribution to improving milk yielding and the shortage of extension workers are solved.