ASSESSING THE ADOPTION AND IMPACT OF RADIO FREQUENCY IDENTIFICATION TECHNOLOGY FOR LIVESTOCK MANAGEMENT AMONG SMALL-SCALE FARMERS IN NYERI COUNTY, KENYA

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17M03EMIT009

A Project Research submitted in partial fulfilment of the requirements for the award of the degree of Master of Science Applied Information Technology in the Department of Computer and Information Technology at the School of Science and Technology of Africa Nazarene University.

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DECLARATION

I declare that this document and research describe the researcher's original work and that researchers have not presented in any other university for academic work.

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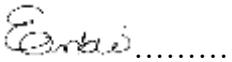


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This research was conducted under our supervision and submitted with our approval as university supervisors.

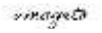
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DEDICATION

I dedicate this work to my mother, Caroline Wangu Muchiri, younger brother James Njoroge and aunt Jennifer Wanjungu Muchiri whose support, encouragement, patience, and prayers throughout the research project.

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Thank God for His insight and wisdom, and to my supervisors, Dr Edward Ombui and Dr Victor Mageto, thank you for your direction and legitimate knowledge throughout the project. I would also like to thank my classmates for continually reassuring me.

May God's blessing arrive.

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ABSTRACT

RFID has been used in the livestock sector to track the location and identify farm animals. The RFID technology is first rated in identifying and tracking livestock inventory. Essential health data is recorded for each animal, managing animal diseases and combating livestock theft. Despite RFID technology's importance in livestock farm management, many small-scale farmers are unaware of its benefits. Financial consequences, operational management of RFID items, environmental concerns, and database administration issues have also hindered livestock management's widespread adoption of RFID technology. The study explored the adoption and impact of Radio Frequency Identification (RFID) technology in the context of livestock management in Nyeri, Kenya. The specific objectives were to; evaluate the Radio Frequency Identification Technology's benefits in the management of livestock among small-scale farmers in Nyeri County, identify the factors that influence the adoption of a Radio Frequency Identification Technology for livestock management among small-scale farmers in Nyeri County, and develop a Radio Frequency Identification framework for the management of livestock in Nyeri County Kenya. Innovation Diffusion Theory and Technology Acceptance Model guided the investigation. The researcher collected quantitative data via questionnaires and interviews. Questionnaires were used to collect data from livestock questionnaires and interviews with industry experts in agriculture and the use of RFID.

The target population was 147,374 livestock farmers in Nyeri County. Data analysis involved descriptive and inferential statistics. Most of the livestock farmers agreed that the use of RFID technology had brought significant benefits. The benefits enabled them to improve livestock production and reduce the cost, enhance the livestock's security and traceability, generate timely, accurate, and granular data helpful in livestock management, and enhance the livestock feeding schedule and rationing monitoring. Other benefits included improved automated livestock monitoring resulting in few labourers, and enhanced ability to correctly trace and identify the livestock and adequately manage the cattle feeding programme. Factors such as technology, cost, environment, facilities, and data management were sufficient explanations for 51.2% of the use of RFID technology for livestock management among small-scale farmers in Nyeri County. The development of the RFID model for livestock management in Nyeri County, Kenya, is based on the benefits of RFID in livestock management and factors that influence the adoption of RFID for livestock management. The study concluded that the development of RFID for livestock management should base on the benefits and challenges of RFID in livestock management and factors that influence the adoption of RFID for livestock management. Since the cost of implementing RFID technology is generally high for an individual, livestock farmers in Nyeri County should consider rolling out the program from a cooperative perspective. The farmers can form groups, and because they have community land, they can start by pulling resources together, which will help alleviate financial challenges and ease negotiations with technology providers.

Given that technology may be complicated for some, Nyeri County, through the county government, should collaborate with institutions that provide training to farmers to offer free training on the benefits and use of RFID technology for farmers. Kenya Agriculture and livestock research organization's primary mandates are to develop disease control technologies and an effective traceability system; RFID is one technology that can solve disease control through identification and tracking. Therefore, the Organisation should ensure they take primary responsibility for managing the data.

DEFINITION OF TERMS

Cost implication factors: refers to expenses incurred in acquiring, installing, and operating RFID technologies in livestock management.

Data management collects, interprets, and uses RFID data in livestock management.

Environmental factors: refers to environmental-related issues that interfere with the installation and operations of RFID technologies, including moisture, temperatures, and canopy.

Global Positioning System: Global Positioning System is a satellite system that uses the difference in the time it takes for waves from different satellites to reach a receiver on Earth to figure out the longitude and latitude of the receiver.

Radio Frequency Identification: A form of wireless communication that incorporates electromagnetic in the radio frequency portion of the electromagnetic spectrum to uniquely recognize an object, animal, or person.

Technological factors: Technological factors include technology hiccups, mechanical damage, environmental damage, tag collisions, and poor print quality caused by electromagnetic fields and nearby electrical equipment. These things can make it hard to use RFID technology to handle livestock.

LIST OF ABBREVIATIONS AND ACRONYMS

EU: European Union

FAO: Food and Agriculture Organisation

GDP: Gross domestic product

GPS: Global Positioning System

HF: High Frequency

IDT: Innovation Diffusion Theory

KSH: Kenyan Shilling

L.F.: Low Frequency

NAIS: National Animal Identification System

RFID: Radio frequency Identification

TOE: Technology Organization Environment Framework

UHF: Ultra-High Frequency

USD: United State Dollar

USDA: United State Department of Agriculture

CHAPTER ONE

INTRODUCTION AND BACKGROUND INFORMATION

1.1 Introduction

Livestock production remains one of the agricultural activities globally. Of the world, 1.3 billion households in developing countries heavily depend on livestock for livelihood and sustenance. FAO (2017) also noted that livestock contributes 40% of the global value of agricultural output and supports the livelihoods and food and nutrition security of almost 1.3 billion households. Livestock production is vital in enhancing the global food requirement of 10 billion populations by 2050 (OECD/FAO, 2020). Thus, proper management of livestock is significant for strengthening optimum livestock production. Ensure the quality and well-being of farmed animals. There is an increasing demand for animal identification and traceability systems using Radio Frequency Identification (RFID). According to Barge, *et al.* (2013), livestock farmers can utilize RFID to increase the efficiency of livestock management and traceability.

RFID technology has been deployed in the management of livestock. RFID is used in the livestock sector to track the location and identify farm animals. Thus, RFID technology has enabled efficient grazing of livestock. It is also a vital technology in managing water points, allocating and distributing animal feed, and improving breeding. Further, recording essential health data for each animal, managing animal diseases, and combating livestock theft have been achieved through RFID technologies. However, the management of livestock using RFID technologies faces challenges the failure of RFID to operate in humid and high temperatures, cost implications, reading range, control of the enormous volume of data produced, and the level of granularity.

Several factors affect the use of RFID technology in livestock management. Several factors exist, including cost, technical feasibility, infrastructure availability, regulatory requirements, and stakeholder engagement. In terms of technology itches, mechanical damage, environmental damage, tag collision, and print quality degradation due to electromagnetic fields and nearby electrical equipment (Khalid et al., 2021) affect the adoption of RFID technology in livestock management. In addition, the failure of tags characterizes the RFID technologies in livestock management. Environmental issues have been found to interfere with the installation and operations of RFID technologies.

In some cases, where RFID tags are used in the identification and traceability of livestock, environmental challenges interfere with the normal operations of RFID tags. Unfortunately, environmental factors like water and canopy substantially impact these two frequencies. When liquids are present, RFID signals are absorbed, reducing or even stopping transmission between tags and readers, while plant canopy may interfere with the transmission of RFID signals. RFID technology installation necessitates a thorough understanding of data management. Reliable data management is necessary to ensure that the large amounts of information generated by RFID systems can be processed effectively. Insufficient expertise and knowledge also characterize the successful deployment of RFID technologies. There is a perception that RFID technology is challenging to implement since it demands high expertise. Livestock farmers have to balance the benefits associated with RFID and the challenges associated with RFID in managing livestock.

Radio frequency identification uses radio signals to wirelessly transmit the identity of an object, item, or person (in the form of a unique serial number) (Adrion, 2018). Readable RFID tags are attached to the object, person, or animal, and the tags can be read and recognized by an RFID reader. The use and consumption of RFID technology have been

growing globally (Dabbene, et al., 2016). The platform, apart from using a data repository through which the RFID tag numbers are attached with animal data records. It introduces re-writable tags for storing information that can identify the animal when it gets lost or even recognize some basic information without contacting the related database (Voulodimos, et al., 2010). In 2014, the world RFID market comprising tags, readers, and software/services for RFID cards, labels, fobs, and all other form factors was worth US$8.89 billion, up from US$7.77 billion in 2013 and US$6.96 billion in 2012. The market value rose from US$12.08 billion in 2020 to US$16.23 billion by 2029 (RFID, 2020).

RFID has been used in the livestock sector to track the location and identify farm animals. The RFID tags are inserted in the animals, or an RFID chip is implanted (Liang, et al., 2015). After installing the RFID tag or implanting the RFID chip, the animal is located, identified, and recognized anywhere within the locality serviced by the RFID technology (Voulodimos, et al., 2010). The RFID technology is first-rated in identifying and tracking livestock inventory. Essential health data is recorded for each animal, managing animal diseases and combating livestock theft. Gough (2021) claims that RFID can track livestock from birth through slaughter. Tools to appropriately value animals, assess farm costs, and correlate data for effective management and reducing losses due to disease outbreaks or thefts will tally for farmers.

Despite the significance of RFID technology in livestock farm management, many small-scale livestock farmers are not adequately conversant in the benefits associated with RFID technology in livestock management. In addition, the adoption of RFID technology in livestock management has been hit by numerous factors ranging from cost implication, the operation management of the RFID items, environmental issues, and difficulties of database administration. Moreover, RFID technology has faced resistance and controversies related to

security concerns of people, data privacy, inconsistent global standardization of RFID technologies, and animal health concerns, particularly for implanted chips that course tumours in animals.

The proposed study seeks a framework for implementing Radio Frequency Identification in livestock management in Nyeri County, Kenya. This chapter provides the background of the study and establishes the research basis and scope. It presents a historical background to the research. It outlines the study problem, the need for research, its purpose and objectives, the research questions, and its justification and significance. It also highlights the study assumptions, limitations, and delimitations and defines its scope and critical terms.

1.2 Background of the Study

The rising demand for livestock products occasioned by the increasing human population and high dependence on livestock products for food has necessitated modernized, efficient, and effective livestock management. The growing demand for subsistence and commercial products has necessitated investment in large-scale livestock farming to meet the demands. Managing large-scale livestock is hectic and costly as it will involve hiring more farm managers and livestock keepers to rear the many livestock on the farm. In addition, keeping essential health data for each animal and managing animal diseases can be problematic when farming large livestock. In that regard, the application of RFID technology in the management of animals has been gaining recognition globally (Adrion, 2018). ISO 11784 and ISO 11785 are the international standards that regulate the radio-frequency identification of animals.

RFID use in livestock management has been associated with significant benefits. It has been used in monitoring animal health and welfare, traceability, market access, and data

management. RFID has been helpful in livestock management. The effectiveness of RFID technology with other livestock identification and tracking methods is far better, a phenomenon attributed to the fact that advanced tracking technologies support it, and it is easy to deploy. RFID has been deployed in different societies.

Australia has used RFID technology to manage livestock since 2005 (Evans & Paterson, 2013). In the same period, the National Livestock Identification System (NLIS) was modified to facilitate the electronic tracking of livestock in Australia. The key objective is proper livestock farm management, providing an accurate track and trace system to assist in a disease outbreak. Hossain and Quaddus (2010) indicated that Australia introduced RFID monitoring and fault prognosis during a livestock disease outbreak. RFID technology's adoption and subsequent implementation in livestock management were based on the benefits of RFID against its shortcomings (Williams, et al., 2019). Government regulations, market pressure to provide animal details during the sale, and the desire for competitive advantage influence the adoption of RFIDs in Australia (Hossain & Quaddus, 2010).

Canada and USA are also significant users of RFID in livestock management. In the United States, the use of RFID in livestock management began in early 2003. The desire to deploy RFID in livestock management was prompted by the need to combat animal disease outbreaks and understand pasture conditions (Ribeiro, 2010).

In 2005, the Canadian government implemented RFID technology to manage disease outbreaks, grazing, watering, audit, and unique animal identification purposes (Hossain, et al., 2017). However, RFID consumer privacy and the use of RFID for other purposes like spying have rocked the successful deployment of RFID in both US and Canada (Ribeiro, et al., 2010).

In the Netherlands, the livestock sector generates some USD 9.5 billion annually (Chainway report, 2019). The significance of livestock to the economy of the Netherlands, better ways of livestock became a priority leading to the emergence of RFID use in 1977. RFID technologies and handheld RFID readers are deployed in livestock food traceability. In Japan, livestock disease outbreaks, market factors, and the need to correctly identify the livestock during selling and consumption promoted the Japanese government in 2002 to use RFID in livestock management. Nonetheless, the use of RFID in the Netherlands and Japan has been undermined by data privacy issues in the use of RFIDs.

In Africa, using RFID in livestock management has been gaining recognition. Botswana, one of Africa's countries practising extensive livestock farming, has employed RFID in livestock management since 2001. The Ministry of Agriculture, using the Livestock Identification Trace-back System (LITS), ensure that cattle in Botswana can be individually identified and traced throughout their lives (Burger, 2004). The use of RFID to manage livestock farming in Botswana was prompted by European Union regulation requiring proper tracking of beef exported to Europe from Botswana. Outbreaks of foot and mouth disease occasioned Europe. Botswana exports 80-90% of its beef product to Europe. The exported beef must be traceable from the packing plant to the exporting country. Across the eastern borders, RFID has been deployed to help combat cattle rustling via querying livestock details using the internet, short messaging, or GPRS technology (Siror, et al., 2010). Similarly, RFID in Nigeria has been deployed to curtail cattle rustling in Nigeria (Ibrahim, et al., 2016). Despite the use of RFID gaining prominence in Africa, the deployment has been marred by inadequate know-how on the operations of RFID in livestock management, technology challenges, and cost implications.

In Kenya, livestock production remains one of the main economic activities for many households. The livestock sector contributes 12% to Kenya's GDP, 42% to the agricultural GDP, and employs 50% of the farm labour force (KALRO, 2020). In Arid and Semi-Arid Lands, livestock production contributes almost 90 per cent of households' livelihood. It accounts for nearly 95 per cent of family income. Kenya's livestock sector has the potential to support sustainable national development through food production, employment, and general economic growth (Kenya Market Trust, 2019). Livestock products form a significant form of food nutrients for many households. Thus, livestock rearing and management rain significant in the quest for food security. The vision 2030 and Big Four Agenda in Kenya recognize food security as one of the pillars. Thus, improved livestock production and management will prove essential in attaining these goals.

The National Census of 2019, Kenya's animal resource base comprised 2.2 million dairy cattle, 559,000 dairy beef, 13 million indigenous cattle, 19.3 million sheep, 28 million goats, 4.6 million camels, 1.2 million donkeys, 443,000 pigs, 30.3 million indigenous chicken, 5.6 million layers, 2.9 million broilers, 561,000 rabbits and 1.2 million beehives and an undetermined number of companion, game, and aquatic animals (KNBS, 2020). Due to the growing need to enhance livestock management and improve livestock identification and traceability in the international market, evaluation of animal disease, spread, and food safety, Animal Identification and Traceability have gained recognition.

Livestock Identification & Traceability Systems (LITS) was revamped to Animal Identification & Traceability (ANITRAC) as a critical plank. Kenya's push for sub-sectors is up to date, commercialization, and improved competitiveness using RFID technologies. The ANITRAC is geared toward modernizing the traditional extensive pastoral production systems. The exact prevalence of livestock theft and cattle rustling creates opportunities for

innovative management of livestock on ICT platforms. Promote partnerships with Kenya's vibrant private sector and other stakeholders in the animal resource industry (Ministry of Livestock, 2020). The RFID animal identification tags in Kenya comprise the indelible Kenya code (KE) alongside the identifier number. Despite the growth in the use of RFID technology in livestock management, the successful adoption of RFID has been argued to be hindered by technology challenges, technical know-how of RFID, cost implications, and government regulation regarding data use of RFID (Galanakis, 2021). In addition, the benefits associated with using RFID in livestock management are not clearly outlined for farmers to decide about implementing the RFID technology.

Nyeri County is located in Central Kenya. The county is between longitudes 36038' East and 37020' East and between the equator and latitude 00 380 south. It covers an area of 3,325 Km^2, according to the 2019 Kenya Population and Housing Census. Crop farming, livestock farming, and business enterprises are major economic activities in the region. Dairy cows, poultry, pigs, goats, donkeys, and sheep are some of the most common livestock species in Nyeri County's traditional livestock production. 85% of the population is involved in dairy, sheep, goats, bees, rabbits, piggery, and poultry husbandry in the livestock sector. According to government estimates, Nyeri County, home to 176,000 dairy cows, produced nearly Ksh 4.3 billion animal products in 2017. Livestock farming has a wide range of issues, including limited pasture and low-quality commercial feeds; animal infections; scarce field officers; high costs of inputs and poor marketing; and many more (Kigen & Ndegwa, 2021).

The usage of high-quality feed, purchased or grown on the farm, by farmers in Nyeri County is a common practice in research studies in this area. Systematic tick and internal parasite control are not well-documented, according to FAO. According to the reports, small-scale methods are being used to combat diseases such as East Coast fever (ECF), a black quarter

(17.5%), foot and mouth disease (7.5%), lumpy skin disease (6.2%), Rift Valley fever (5.5%), and anthrax (4.8%). Mammary illnesses like mastitis and brucellosis are also common, with prevalence rates ranging from 30 to 45 per cent (Rahman et al., 2021). For every $1 invested in livestock interventions that enhance resilience, farmers found a return of $5.5 (Khan et al., 2021).

As a result, effective data monitoring, information sharing, and collaboration are fundamental to the development of this industry. Cattle management is one area where RFID technology is essential. Consequently, this project aims to build an RFID model that may be implemented in cattle husbandry in Nyeri County. Despite the prominence of RFID in livestock management in Nyeri County, many livestock farmers are not adequately aware of the cost-benefits associated with using RFID in livestock management. In addition, proper deployment of RFID has been argued to be hindered by technology challenges, technical know-how of RFID, cost implications, and government regulation regarding the use of RFID.

1.3 Statement of the Problem

Livestock farmers in Nyeri County continue to experience problems related to livestock management. Tracking and monitoring livestock disease outbreaks results in massive losses to farmers. Moreover, the ravaging drought has made it difficult for livestock farmers in Nyeri County to track, monitor and control the usage of pasture and water among the livestock animal. Furthermore, health issues using RFID, data privacy, and omission of the international status regarding RFID remains the fundamental problem among livestock farmers using RFID to monitor livestock.

Livestock farming in Nyeri is also hampered by limited pasture and frequent animal disease outbreaks. Furthermore, trading livestock and products both locally and internationally requires proper identification and traceability to guarantee the safety of products sold to

consumers. RFID has gained significant recognition in Nyeri County, the demand to enhance livestock management through improved pasture management, identify and combat animal disease outbreaks, spread and food safety, and improve livestock identification and traceability in the international market.

Despite the prominence of RFID in livestock management in Nyeri County, many livestock farmers are not adequately aware of the cost-benefits associated with using RFID in livestock management. In addition, proper deployment of RFID has been argued to be hindered by technology challenges, technical know-how of RFID, cost implications, and government regulation regarding the use of RFID. However, empirical studies have not been conducted to identify the factors influencing the adoption of RFID for livestock management in Nyeri County and whether small-scale farmers are reaping any RFID benefits in livestock management. This study sought to evaluate the Radio Frequency Identification technology's benefits in the management of livestock among small-scale farmers in Nyeri County, identify the factors that influence the adoption of a radio frequency identification technology for livestock management among small-scale farmers in Nyeri County, and develop a radio frequency identification framework for the management of livestock in Nyeri County Kenya.

However, limited empirical studies have focused on the use of RFID in livestock management by narrowing to cost against benefits of RFID and factors that influence the adoption of RFID. Available studies focused use of RFID in livestock management in advanced countries. Barge, et al. (2013) looked at RFID use in livestock management in Canada but did not indicate possible factors that affect the imp mentation of RFID. A study by Hossain and Quaddus (2019) investigated factors that affect the adoption of RFID in Australia and found that external environment, technological characteristics, and organisational factors are significant for RFID adoption. Local studies like that by Ibrahim, et

al (2016) focused on using RFID in taming cattle rustling in Nigeria. Likewise, Siror, et al. (2010) studied using RFID to combat cattle rustling in East Africa. Both Siror, et al. (2010) and Ibrahim, et al (2016) did not explore the cost against benefits of RFID in livestock management.

Moreover, the studies did not examine the factors that influence the adoption of RFID in livestock management. This research offers a framework for implementing radio frequency identification in livestock management in Nyeri County, Kenya. It focuses on RFID benefits and factors that influence its adoption.

1.4 Purpose of the Study

The study aims to propose a framework for implementing radio frequency identification in livestock management in Nyeri County, Kenya, focusing on RFID benefits and factors that influence its adoption.

1.5 Objectives of the Study

1.5.1 Overall objective

The study's objective was to explore the adoption and impact of radio frequency identification technology for livestock management among small-scale farmers in Nyeri County, Kenya.

1.5.2 Specific objective

The specific objectives of the study are:

i. To identify the factors that influence the adoption of a Radio Frequency Identification Technology for livestock management among small-scale farmers in Nyeri County.

ii. To develop a Radio Frequency Identification framework for the management of livestock in Nyeri County, Kenya.

iii. To evaluate the Radio Frequency Identification Technology's benefits in livestock management among small-scale farmers in Nyeri County.

1.6 Research Questions

i. What factors influence the adoption of a Radio Frequency Identification for Technology livestock management among small-scale farmers in Nyeri County?

ii. Which specific Radio Frequency Identification framework can be used to manage small-scale livestock farmers in Nyeri County?

iii. What are the benefits of Radio Frequency Identification technology in livestock management among small-scale farmers in Nyeri County?

1.7 Research Hypothesis

H_{01}: Technology-related factors, cost implication factors, environment and facility factors, and data management factors have no significant influence on adopting a Radio Frequency Identification Technology for livestock management among small-scale farmers in Nyeri County.

1.8 Significance of the Study

The proposed study will be significant to practice, policy, and scholars. For practice, the study will illuminate the benefits of using RFID in livestock management in the study area. The small-scale livestock farmers in Nyeri County can reap the benefits of RFID. To increase productivity, enhance the quality of their products, manage the outbreak and spread of livestock diseases, and make livestock management more efficient, profitable, and productive. By understanding RFID's benefits against associated demerits implication,

livestock farmers in Nyeri County can make informed decisions regarding implementing RFID.

In the policy realm, the study findings will be significant to policymakers and regulators, including the Ministry of Agriculture and Livestock. The Ministry of Agriculture and Livestock, through the ANITRAC, may formulate policies. Improve the commercialization and competitiveness of the livestock subsector through RFID by following these guidelines for the technology's application in livestock management. Privacy concerns have also plagued RFID adoption due to instances of eavesdropping. The study's findings will advise security agencies on how to regulate RFID use best. The study will also benefit future scholars and researchers studying RFID use, particularly livestock management. Thus, the funding will be a reference for future scholars and researchers studying RFID use in livestock management and factors that influence the adoption of RFID.

1.9 Scope of the Study

The study will focus on **s**mall-scale farmers in Nyeri Country, where 85 per cent of the population engages in livestock farming, are included in the study. The focus is to evaluate the Radio Frequency Identification technology’s benefits in managing livestock among small-scale farmers in Nyeri County and identify the factors that influence the adoption of the radio frequency identification framework for livestock management among small-scale farmers in Nyeri County. Further, the proposed study will seek to develop a radio frequency identification framework for livestock management in Nyeri County, Kenya.

In terms of methodological scope, the study will employ a mixed methodology approach to address the research objectives using quantitative and qualitative methods. The study focused

on small-scale livestock farmers in Nyeri County. The study population will be 147,374 small-scale cattle farmers in Nyeri County. The sample population will be 384 small-scale cattle farmers in Nyeri County, to be derived using Fisher's formula. The Innovation Diffusion Theory and Technology Acceptance Model will anchor the study.

1.10 Delimitation of the Study

The study will only focus on cattle framing rather than the entire livestock sector comprising cattle, poultry, pigs, goats, camel, sheep, donkeys, and horses. Cattle farming is the primary emphasis of the research, rather than the broader livestock industry. It would be challenging to cover all cattle industry aspects in one study. Small-scale cattle farmers in Kenya's Nyeri County were the sole focus of this study. The study will focus on cattle farming in Mukurweini, Tetu, Kieni, Mathira, Othaya Mukurweini, and Nyeri Town Sub counties. Although the study is focused on cattle ranching, the findings will have a wide-ranging influence on other subsectors of livestock management not studied.

1.11 Limitations of the Study

The wet season in Nyeri County may have constrained the study, which prevented access to some of the study's locations. There was no way to get about because of the bad weather. However, the researcher will time favourable weather conditions to conduct the study, particularly January-March and October-December.

The respondents may also hesitate to provide complete information about the use of RFID for fear that the information will be used to investigate how they use RFID. However, the limitation will be mitigated by assuring the respondents that the data is meant for academic purposes only. Regarding methodological limitations, the study may not gather sufficient

information on the use of RFID as the technology is still new among some small-scale cattle farmers in the study region. The study will employ quantitative and qualitative approaches through structured and open-ended questions to address this limitation.

1.12 Assumptions of the Study

For the survey to be completed on time, the researchers presume that the respondents will cooperate and offer the necessary information. They expect that Radio Frequency Identification will change livestock management in the county by lowering the cost of production.

1.13 Theoretical Framework

The Technology Acceptance Model and Innovation Diffusion Theory guided the study.

1.13.1 Technology Acceptance Model

Technology Acceptance Model (TAM), started by Davis (1989), postulates that the use and acceptance of a particular technology are anchored on the benefits to be derived, alongside ease and use of the technology (Surendran, 2012). In the TAM model, perceived usefulness and ease the desire to use a particular system. The ease of use and perceived usefulness are critical features that determine the actual use of the system. According to Venkatesh *et al.* (2012), a particular technology's attitude, usefulness, and ease of use impact its actual use. Perceived ease of use defines a system's user-friendly, while perceived usefulness outlines the benefits to be accrued from a system (Davis & Venkatesh, 1996).

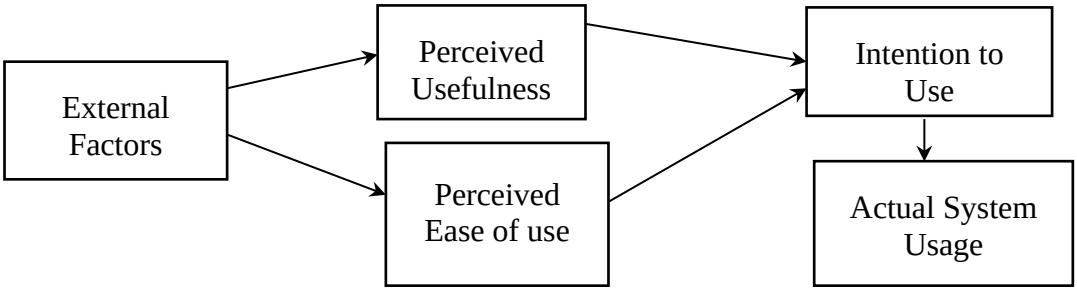


Figure 1.1: Technology Acceptance Model

(Source; Davis, 1989)

Nonetheless, the TAM model has been criticized regarding its ability to explain the behaviour of individuals. TAM is not sufficiently robust and reliable in explaining users' behaviour when it decides to acquire, accept or reject a particular technology (Malatji, Eck & Zuva, 2020). In addition, Ajibade (2018) noted that TAM is more suitable for individual use and not institutions or organizations that require further ICT integration. Further, though TAM has received much attention from scholars, TAM fails to explicitly explain its use and application in e-government systems (Chandio et al., 2017).

Tam's model is relevant to understanding the use of RFID technologies in livestock management. TAM argues that using a particular technology is a function of the benefits to be accrued and the ease of using the system. The benefits of using RFID include managing livestock disease outbreaks, managing grazing pastures, watering livestock, traceability, and unique animal identification purposes to tame cattle theft.

1.13.2 Innovation Diffusion Theory

The theory of Innovation Diffusion brought forward by Rogers (1962) is based on the notion that innovation entails the planned or spontaneous spread of ideas. According to Rogers, 1995, innovation refers to a theory or practice perceived as new or emergent. Diffusion is a process through which innovation is communicated to the members of a given social system using specific channels (Orr, 2003). The success of innovation depends on five qualities, including relative advantage, compatibility with existing values and practices, trialability, simplicity, and ease of use, and should have visible results (Kaminski, 2011). In diffusion of innovation, the innovations change, not the people.

Developing new technology, apparatus, or technique is innovation (Dearing &Cox, 2018). Spreading ideas, concepts, skills, and knowledge throughout a community is diffusion. Innovations or technologies are adopted and propagated by local or significant populations according to the innovation diffusion theory (IDT). “Innovation-decision” is used in the Innovation Diffusion Theory. Dearing and Cox (2018) state that people’s attitude toward change develops as they learn more about new technology. An individual decides whether to accept or reject the invention after they have an opinion. They implement the invention and affirm their decision if they agree.

The procedure has five stages; the first is the Knowledge stage (Dearing & Cox, 2018). An individual is first exposed to technology and learns how it works during this time. This level focuses on three sorts of knowledge: Knowing that technology exists is referred to as gaining awareness of its existence. Knowledge gained about how to operate a piece of technology is referred to as “how-to” knowledge. Technology’s basic concepts, such as how the internet works, are called principles-knowledge (Ali et al., 2021). In the absence of principles knowledge, use may be discontinued. Principle knowledge is not required for acceptance and

use. Mass media is the primary source of knowledge in today's world. Additionally, early adopters or change agents who have learned how to use the technology play an essential part in the success of a shift (Mohammadi, et al., 2018).

The second step is to persuade. At this stage, people seek information on the technology to determine which sources of information are reliable and how other people feel about it. Believing something good or bad about technology does not always equate to using it. Positive feelings about technology do not always indicate that it will be used well. The knowledge, attitudes, and practice (KAP) gap occur when this happens (Jamshidi & Kazemi, 2020). The final stage is deciding. People are in the decision-making stage when they participate in actions that lead to accepting or rejecting technology or innovation. Many people are looking for a means to try out new technologies in a small way before making a more significant commitment. Allowing individuals to verify whether the technology offers a benefit will significantly increase adoption if it does (Gu & Black, 2020).

People can reject technology at any point in the process. According to Gu and Black (2020), it is possible for someone to either actively or passively reject a new technology if they do not take the time to learn what it means to use it. Adopting the technology is followed by the implementation for the person who decides to adopt it. Several factors can go wrong during implementation, which may lead to the technology being discontinued. There may also be difficulties in implementing the technology to its fullest potential. Change agents help handle these difficulties and educate people on using the product.

Re-inventors, or people who discover new and better ways to use technology, might motivate those adopters who have difficulty implementing it. Individual customization is encouraged by re-inventors (Lee, 2021). The final stage is confirmation. They seek support from others in their decision to employ the technology.

The adoptee will seek reassurance because they want to feel confident in their choices. However, if they receive too much contradictory information, they may stop using it altogether. When a discontinuance is applied, either the adopter substitutes the technology or is dissatisfied. When a person returns to an approach with a competitive innovation, they believe to be superior to the preceding, known as replacement discontinuation.

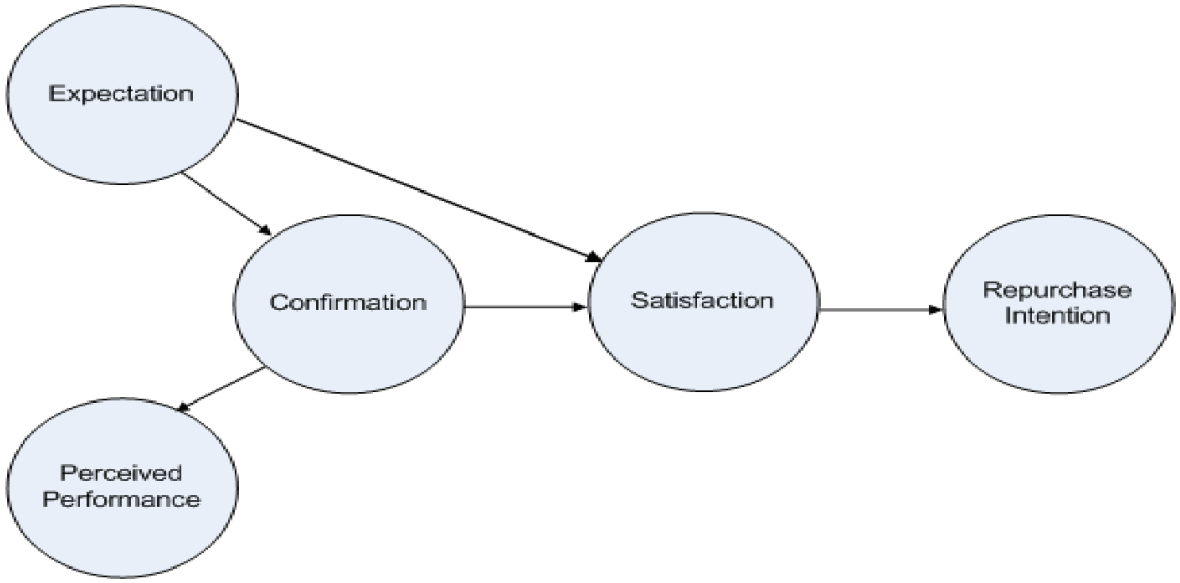


Figure 1.2: Innovation Diffusion Model (Bhattacherjee, 2001)

The innovation diffusion theory is relevant to understanding technological innovation in RFID use in livestock management. Innovation diffusion argues that technology is easy and efficient, enhancing cattle's traceability, managing cattle grasslands, and combating cattle disease outbreaks and spread. This medium will eventually lead to enhanced cattle production in Nyeri County.

1.13.3 Technology-Organization-Environment Framework

This study was anchored on the technology-organization-environment (TOE) framework. The TOE framework was advanced by Tornatzky and Fleischer (1990), which uses three elements that influence technological adoption: environmental, organizational, and technological

factors. The environmental factors surrounding a firm include multiple stakeholders, such as industry members, competitors, suppliers, customers, the government, and the community (Angeles, 2013). They can influence how a firm interprets the need for innovation, its ability to acquire the resources for pursuing innovation, and its capability for actually deploying it. Changing markets and competitive conditions prod firms to use various forms of innovation. Government regulation is also another powerful tool for constraining a firm's operational activities, increasing costs of production, and instigating an investigation of technologies that must meet specified mandatory criteria. Finally, dominant customer firms could exert power to shift their suppliers' production activities and business processes to comply with their requirements.

Technological factors under TOE suggest that a business should consider the characteristics of the technological structure of its internal and external settings (Justino, et al., 2022). Taking cognizance of the existing technological structure would help the firm define its limitations and quickly identify the relevant technology in the market. Technological factors may include the type of technology, cost, acquisition, deployment and maintenance. On the other hand, the organisational elements consider the characteristics of the firm and its resources, including the quality of the employees' technology usage expertise, organizational structure, and amount of resource slack (Matikiti et al. 2018; Nguyen, et al., 2022).), and firm's size (Justino, et al., 2022).

The TOE framework was relevant to this study in anchoring the factors that influence the adoption of an RFID for livestock management among small-scale farmers. According to the TOE framework, the factors take three contexts, environmental, organisational and organisational factors. Thus, the TOE framework proved helpful in identifying the technological, environmental and organisation/ individual factors that determine the adoption of RFID in Nyeri County. The cost of acquisition, deployment and maintenance of RFID falls

under technological factors; humid and temperatures that affect the use of RFID in livestock fall under the category of environmental factors, while the availability of resources to acquire RFID and know-how skills fall under the category of organisational factors.

1.14 Conceptual Framework

The conceptual framework presented is intended to depict how the study's variables are interrelated. Figure 1.3 depicts a conceptual framework concerning factors that influence the adoption of RFID for livestock management.

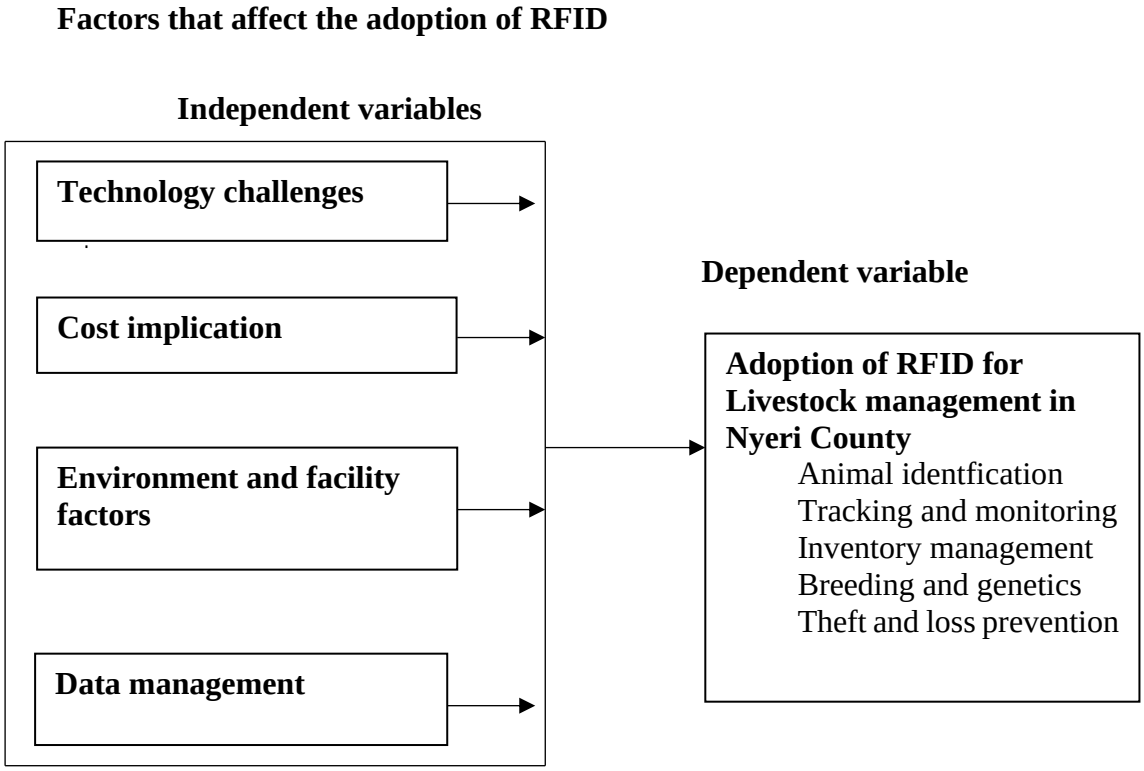


Figure 1.3: Conceptual framework of the study

The study sought to develop a framework for implementing RFID in livestock management among livestock farmers in Nyeri County. One of the specific objectives was to identify the factors that influence the adoption of a radio frequency identification framework for livestock management among small-scale farmers in Nyeri County. The factors investigated include

technological, cost implication, environment and facility, and data management factors. It is postulated that technological, cost implication, environmental and facility factors, and data management factors significantly influence the adoption of RFID for livestock management in the study locale. The study's conceptual framework is different from other scholars' as it incorporates all the insignificant factors identified in the literature that affect the deployment of RFID in livestock management. Technological factors were established to influence RFID adoption by Jung and Lee (2015), OECD (2018), and Abugabah, et al. (2020), while Ruiz-Garcia and Lunadei (2011) identified cost implications as the main factor.

On the other hand, other scholars view cost implications as a significant factor influencing the deployment of RFID technologies in livestock management (Hammer, et al., 2017; Zhang, et al., 2017). However, studies that do not pinpoint data management and privacy issues have been introduced in this study. The current study postulates that technological, cost implication, environmental and facility factors, and data management factors significantly influence the adoption of RFID for livestock management in Nyeri County.

Furthermore, adopting RFID technology for livestock management in Nyeri County can bring several benefits and improve the efficiency of the livestock industry. Here is how RFID can be utilized for livestock management:

Animal Identification: RFID tags can be attached to livestock, such as cows, goats, or sheep, to identify each animal uniquely. These tags contain a microchip with a unique identification number that RFID scanners can read.

Tracking and Monitoring: RFID readers placed at various locations, such as feeding areas, water troughs, or milking stations, can automatically detect and record the presence of tagged animals. This data can be used to monitor animal movement, behaviour, and health conditions.

Disease Control and Biosecurity: RFID technology can assist in disease control by enabling quick and accurate identification of animals. In the case of an outbreak, the system can trace the movement of infected animals, facilitating targeted intervention and preventing the spread of diseases.

Inventory Management: RFID tags can also be used for tracking livestock inventory. Scanning animals as they enter or exit a farm can maintain accurate livestock number records. This information is valuable for farm planning, resource allocation, and meeting market demands.

Breeding and Genetics: RFID tags can store information about an animal's lineage, health history, and breeding records. This data can assist farmers in making informed decisions about breeding programs, optimizing genetic selection, and improving overall herd quality.

Record Keeping and Traceability: RFID systems provide a reliable and automated method of recording data related to livestock management. This includes information on vaccinations, treatments, feeding schedules, and other essential records. Accurate and easily accessible records can enhance traceability and compliance with regulations.

Theft and Loss Prevention: RFID tags act as a deterrent against theft and aid in recovering lost animals. If an animal goes missing or is stolen, the RFID tag can help in its identification and subsequent retrieval.

Adopting RFID for livestock management in Nyeri County can enhance operational efficiency, improve disease control, enable better breeding practices, and promote the overall welfare of livestock.

1.15 Definition of Terms

Livestock management: refers to the rearing of cattle, poultry, pigs, goats, camel, and sheep, donkeys, horses, among others, for domestic and commercial purposes (FAO, 2017).

Radio Frequency Identification is an automated system that uses electromagnetic waves to read objects from a distance without having a contact and direct line of sight. It uses a system to wirelessly transmit the identity of an object, item, or person (in the form of a unique serial number) using radio signals (Voulodimos, et al., 2010).

RFID database: refers to the central system or server with details of the object or animal to be tracked. Communication occurs between the database, RFID tags, and RFID readers with RFID and RFID database (Hossain et al., 2017). In this study, the database will be the handled mobile phone because small-scale farmers have it.

RFID readers: also called a scanner or interrogator, is a data capture and identification device that uses a radio frequency electromagnetic field to stimulate a data response from a transponder (Williams, et al., 2019).

RFID tags refer to objects with electromagnetic force installed on animals or cars for easy traceability. Most RFID tags used in the livestock industry are low-frequency tags at a rate of 134.2 kHz (Lowerison et al., 2021).

1.16 Summary

This chapter has outlined the background of the study; it introduces the focal areas of research. The chapter then delves into the research problem and reviews the same in-depth. The chapter outlines the purpose of the study and why the body of work is essential; the research questions and objectives also highlight the study's primary justification and value. The limitations and delimitations of the study consider before progressing to the definition of terms which further sought to operationalize the terms used in this study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the theoretical literature of the study. The chapter also outlines a critical review of empirical literature per the study's objectives. The chapter ends with a summary of the literature review and research gaps.

2.2 Empirical Literature Review

A review entails critically analyzing past studies while identifying knowledge gaps that warrant the current study. The empirical literature review evaluated the Radio Frequency Identification technology's benefits in livestock management. These factors influence the adoption of a radio frequency identification framework for livestock management and the development of a radio frequency identification framework for livestock management.

2.2.1 Factors that influence the adoption of Radio Frequency Identification Technology in the management of livestock.

The successful deployment of RFID is dependent on serval factors. The adoption of RFID is affected by varied factors, including technical challenges, cost implications, environment and facility challenges, and data management and maintenance.

In terms of technology itches, mechanical damage, environmental damage, tag collision, and print quality degradation due to electromagnetic fields and nearby electrical equipment (Khalid et al., 2021) affect the adoption of RFID technology in livestock management. In addition, the failure of tags characterizes the RFID technologies in livestock management. However, Gu and Black (2020) noted that the average rate of tags not interacting with the reader is relatively low. RFID tags failed at a rate of 0.21 per cent in a Canadian study of

feedlot cattle. Less than 0.010 per cent of animal ID representatives estimate this figure (1 in 1,000 RFID tags fails). Quality control and testing are in place by several reputable tag companies before sending tags to ensure they work correctly. Under field conditions, the RFID tags' retention rates were between 97% and 98%. The animal's age, tag placement, illnesses, and physical surroundings can all affect the likelihood of a tag being retained.

A study by OECD (2018) on OECD Policy Guidance of RFID technologies identified that the laws of physics impose technical challenges, such as interference, power management, reflection, and signal attenuation. Similarly, Hossain and Quaddus (2012) studied the antecedents of the continuance intention of RFID technology in Western Australian farms using a quantitative research approach to establish that the technology influences RFID adoption. In contrast, the continuance of RFID technology depends on confirmation and satisfaction from using the technology.

Environmental issues have been found to interfere with the installation and operations of RFID technologies. In some cases, where RFID tags are used in the identification and traceability of livestock, environmental challenges interfere with the normal operations of RFID tags. HF and UHF frequencies are the most used for RFID technology applications since they are the most widely available. Unfortunately, environmental factors like water and canopy substantially impact these two frequencies. When liquids are present, RFID signals are absorbed, reducing or even stopping transmission between tags and readers, while plant canopy may interfere with the transmission of RFID signals. Metal is another environmental aspect to consider. RFID can be deflected by metal. However, the solution is to create a channel for the radio waves to flow through the substance (Ula, et al., 2021).

A study by Ruiz-Garcia and Lunadei (2011) on the role of RFID in agriculture, operation in harsh environments, dirt, extreme temperatures, and reduction of signal strength due to propagation in crop canopy influenced the successful implementation of RFID technologies. Employing a literature review, Mosadegh Sedghy (2018). A study on the evolution of RFID in agricultural cold chain monitoring mentioned that RFID tags' readability is sensitive to environmental factors such as extreme temperatures, dust, moisture, the presence of metallic objects, and the high-water content of tagged materials. Nonetheless, Sedghy (2018) did not quantify the impact of environmental challenges on implementing RFID technologies.

The installation of farm animal RFID systems could be too expensive. According to Khalid et al. (2021), small farmers will go out of business because of the costs associated with RFID livestock identification. Each head of livestock or poultry would have to be registered and remunerated for the annual registration fee for small-scale producers. Though accurate, large-scale livestock growers and organizations can use this technology to compile official records, choose appropriate base stocks for small-scale farmers, and breed these animals accordingly. To avoid paying the cost of owning one animal, big herds of animals travel through the production chain as a unit, allowing corporate farms to quickly obtain the technology (Barge et al., 2020). Small-scale farms may not use RFID technology entirely, but they may use animal identification as a tracking device to reduce theft.

An estimated minimum cost of $2.08 for large producers and as high as $17.56 per head for smaller operations, with an evaluated mean price cow/calf producer of $6.26 per animal, was found to be the cost of becoming NAIS compliant for a United States beef producer in 2017(Barge et al., 2020). The cost of RFID tags may vary based on the quality, maker, and technology used (Smart, et al., 2010). Because of the higher costs associated with RFID

acquisition and maintenance, small-scale livestock farmers may find it challenging to maintain the use of RFID in the identification of their livestock.

Utilising a quantitative approach, Hammer, et al. (2017) conducted a cost-benefit analysis of a UHF-RFID system for animal identification, simultaneous detection, and hotspot monitoring of fattening pigs and dairy cows. The costs associated with the UHF-RFID system include material costs (hard and software as well as initial fitting with UHF ear tags for dairy cows), fitting and installation costs, costs occurring on an annual basis for new UHF transponder ear tags, energy costs, and costs for depreciation and interest. On the same note, a study by Chudy-Laskowska (2018) on factors influencing the decision to implement an RFID system using questionnaire-based surveys established that the cost of system implementation is seen as the most significant factor in an RFID system.

Zhang, et al. (2017) studied the application of RFID in the agricultural product industry using a literature-based review. The cost issue is an important limiting factor in implementing RFID technology. It includes the cost and use of tags and readers, other hardware devices, management system software upgrades, and follow-up system maintenance costs. Smart, et al. (2010) studied the costs of adopting RFID technologies in supply networks. Shear, et al. (2019), in a study on the implementation & Economic Impacts of a Traceability Program on the Beef Industry Stakeholders, identified the cost of RFID tags, installation, and operations as significant costs associated with using RFID. However, the studies did not indicate the extent to which the mentioned costs impact implementing RFID-supported devices.
RFID technology installation necessitates a thorough understanding of data management. Reliable data management is necessary to ensure that the large amounts of information generated by RFID systems can be processed effectively. Large amounts of RFID data and

data integration across numerous facilities will provide farmers with hurdles in RFID data management.

As previously indicated, various livestock tags can generate vast data using RFID systems, resulting in information overload. For this topic, the technology demands robust IT systems to handle the issue's complexity.

Jung and Lee (2015), using a systematic review of RFID applications, found that the diffusion and applications of RFID can involve unexpected disadvantages, including technological deficiency, uncomfortable privacy issues, and unequal distribution of digital power and literacy. Likewise, Hossain, et al. (2017), studying the development and validation of a two-staged adoption model of RFID technology in livestock businesses utilising qualitative field study, found that technological interoperability and data inconsistency significantly influence the acceptance of RFID technology in livestock businesses.

Insufficient expertise and knowledge also characterise the successful deployment of RFID technologies. There is a perception that RFID technology is challenging to implement since it demands high expertise. Many small firms have had challenges in piloting the technology due to a lack of competence in the industry. From the user's standpoint, a lack of understanding of RFID technology may result in dissatisfaction. Barcode technology is cheaper than RFID technology, which may make users hesitant to utilize it in studying the human brain. Eighty per cent of companies using RFID technology find that they lack the necessary skills and resources to implement it (Popova, et al., 2021). Finding local professionals with RFID deployment knowledge is a significant challenge. As a result, learning about RFID technology is essential in the long term.

Abugabah, et al. (2020), reviewing the challenges and barriers to implementing RFID technology in the Healthcare sector, found operational complexity, lack of technical expertise, and knowledge in utilising RFID. Though the study focused on the use of RFID in the health sector, the technological challenges can also be studied in the context of RFID use in livestock management. Further, Pivoto, et al. (2018), studying the scientific development of innovative farming technologies and their application in Brazil, also identified that technical expertise and knowledge impacted the use of RFID by livestock farmers in Brazil.

2.2.2 Developing a radio frequency identification framework for the management of livestock.

The RFID model framework development for livestock management has to consider the benefits and costs associated with it (Voulodimos, *et al.,* 2010). The process requires acquiring the necessary software and hardware materials and expert knowledge. The platform m architecture will comprise.

a. Radio Frequency Identification

A radio signal is used in RFID technology to identify individuals or objects. No physical closeness or sightline is required to read the data in the "tag" wireless gadget. RFID is not an invention; it was used in aircraft during World War II to track down the enemy (Greenwood, Gardner & Ferguson, 2018). An RFID system's operational range depends on several variables, including the operating frequency, tag size, material type, and whether the tag is battery-operated (passive or active). In contrast to passive RFID tags, active RFID tags are equipped with a radio transmitter powered by rechargeable batteries (Le Breton, et al., 2022). The range of communication is long, but the cost is high. An RFID passive tag does not have a power supply; instead, it is powered by the reader. Passive tags are likewise more cost-

effective and have a limited range of transmission. Power is drawn from the reader to communicate with semi-passive tags (Greenwood, Gardner & Ferguson, 2018).

a. Radio Frequency Identification for Livestock Management

RFI is a method that uses radio signals to wirelessly identify items by their unique sequence of numbers or letters. However, RFID systems come in a variety of shapes and sizes. RFID ear tags for cattle were the first certified by the United States Department of Agriculture (USDA). Using an RFID system in farm management will benefit many farmers by automating data entry and retrieval. An RFID system for animal identification has four virtual components:

Ear tag transponder—the electronic data source contained in the ear tag that remains with the animal to be identified. It has a microchip that stores the unique identifier.

• Transponder – the transceiver or reader retrieves the transponder. A radio transmitter and antenna in one. An RFID transceiver can either be part of a permanent group where the animals pass or a hand-held unit that can be moved to the animals' location with the RFID tags.

Data accumulator- a data accumulator is a device that stores or accumulates data received by the transceiver. Personal digital assistants (P.D.A.s), computers, and other electronic devices are examples of data accumulators. The software that does the processing turns raw data into something that can be used. The most critical information to identify an animal would be a unique 15-digit number. Other data management systems may be able to use imported information. Inductively coupled transponders are the most frequent in RFID animal identification systems. For these transponders, the power comes from modules built inside the transponder, which generate electromagnetic fields.

Radio Frequency Identification Technology

a. RFID Tamperproof Ear Tag

A reader activates a radio frequency device embedded in RFID tags. There is no need to write down the tag numbers because the RFID tags are read electronically. As a result, the system is less prone to errors, making it easier to administer. However, the reader is pricey, has a short battery life, and requires internet access to consult the National database at every step in the value chain when movement or death occurs.

Table 2.1: Advantages and disadvantages of RFID Tamperproof Ear Tag

Advantages	Disadvantage
The reader quickly registers each animal recorded with an RFID tag	The tag can be cut off and removed
Quick database registration of each animal identifies ownership.	It requires a reader with unlimited battery life and the internet at a particular access point.
It is a system that easily transfers the information from the animal onto the database.	It is an expensive system to implement.

b. RFID Bolus

The RFID bolus is an injection of bioglass given intramuscularly. A balling gun provides the medicine orally into the ruminant's stomach. The RFID bolus is placed in the rumen and cannot be removed by a criminal.

Table 2. 2: Advantages and disadvantages of RFID Bolus

Advantages	**Disadvantage**
An RFID device lies in the rumen, is tamperproof, and can significantly reduce cattle rustling.	It is expensive and costs more than a tamper-proof tag.
Can be recycled	Recycling in practice is complex and does not visually identify the animal.

a. RFID Implantable Microchip

Microchips forms identification involves implanting an electronic chip, with a mini radio transponder and antenna, underneath an animal's skin near the base of the ear or the neck between the shoulder blades.

Table 2.3: Advantages and disadvantages of RFID Implantable Microchip

Advantages	**Disadvantage**
RFID device implanted under the skin.	It is cheaper than the Bolus and is, to some extent, tamperproof.
Can be recycled	Recycling in practice is complex and does not visually identify the animal.

a. Radio Frequency Identification Operating Frequency

RFID technology in livestock management systems is one of the most impressive applications of this technology. Low-frequency (L.F.), high-frequency (H.F.), and ultra-high

frequency (UHF) RFID systems are classed according to the frequency bands used. The frequency bands employed in livestock management systems are classified in this study.

b. Low-Frequency Radio Frequency Identification-Based Livestock Management System

The low frequency (L.F.) band is commonly used for livestock identification systems (125-134 kHz). RFID tags were implanted in dairy cows in the 1970s by Matt Lezin and Tom Wilson to monitor and identify the animal's temperature. A single animal's health, ovulation, location, monitoring, and identity are tracked. It was also ensured that no animal was overfed by using automatic feeding. Electronic feeding systems for sows have been created (Borges, Bernadi & Petrin, 2018). Automated weighing and identification of sows is the goal of this project. The scale locks when a starved sow arrives to prevent another sow from entering. Using an RFID tag implanted in the animal's ear, its weight may be read, and the data kept on the computers.

The type of feed is specified based on the dispenser's collected data. A low-energy feeding area is designated for animals that need it. In contrast, a high-energy feeding area is designated for those that do not. Automated doors, drafting, milking, and feeding with RFID technology are some ways to improve farm management (Khan et al., 2021). The case study includes automated opening and closing doors, prepping, feeding, and draining. As long as the farmer is pumping enough, animals will get the food they need thanks to the automated feeding system. On the other hand, a computerized drafting system can isolate cows needing monitoring from the rest of the herd.

Data about individual cows, such as demographics, health status, and milk production, is stored in the centralised animal management database. This feature allows the host computer to instantly see the precise requirements of each cow as they pass by the RFID scanner.

Unified livestock management using low-frequency radio frequency identification (LF RFID) technology was implemented in 2010 and has turned out positively. Various animal information categories, such as diet, history, behaviour, and productivity, are stored and managed by the platform (Landaluce, et al., 2020). In addition to the mobile RFID system, the local database, and the central database, there are three other sub-systems. The central database stores information on the farm (address, phone number), the veterinarians on staff, a list of authorized vets, and the animals maintained there.

The animals' records are in detail in the area's databases. Every farm has its local database linked to a centralized database. According to Landaluce, et al. (2020), animal breeding can benefit from the widespread usage of RFID technology. RFID readers are positioned in the funnel-shaped milking and feed regions, where L.F. tags are attached to each animal's collar. It includes a graphical user interface (G.U.I.), a database, and other components (Adrion et al., 2020). Fodder area scanners scan an animal tag to determine how much food each animal receives. Each animal's milk is tested and stored in a database to determine its quality and quantity.

An online livestock management system was proposed by scientific researchers (Hosseinzadeh, et al., 2020). An RFID system, Web 2.0, and mobile-cloud architecture are used in the proposed system. In addition, the order uses the Occasional Connected Form (O.C.A.). Field employees can access that mobile devices' cache memory. The system regularly connects to the primary database to retrieve the most recent data and then save it in the local cache. Each animal's data is stored in a centralised database. The website mimics a desktop experience, allowing users to access data and install new software without leaving their browsers. The RFID bolus is an injection of bioglass given intramuscularly. A balling

gun provides the medicine orally into the ruminant's stomach. The RFID bolus is placed in the rumen and cannot be removed by a criminal.

Unless otherwise specified, the data in the local database and subsequent updates to the central database are synchronized, allowing users to see animal information and its position. There is no need to purchase gear, software, or license fees for cloud computing, which reduces capital costs. Data can be quickly restored and backed up. The third-party cloud service provider has access to the company's sensitive data housed in the cloud. As a result, it raises serious security concerns.

A comprehensive RFID-based system for small-scale dairy farmers was created to improve productivity (Rogerson & Parry, 2020). The approach ensures that livestock insurance premiums are not misused. Periodically, the system gathers data on its performance. In addition to the central and local servers, the LF RFID reader, tag, laptop, and universal serial bus (USB) modem is used in the system. Whenever a mobile RFID system reads an animal tag for the first time, it will be registered in the insurance system. After that, the laptop was used to save the animal's details and the owner's name. Any changes in animal information (e.g., diseases, new owners) stored in the insurance database will be transferred through the Internet.

c. High-Frequency Radio Frequency Identification -Based Livestock Management System

HF RFID systems have a communication range of 10 cm to 1.5 m and operate at a frequency of 13.56 MHz in some applications. A passive HF RFID device was used to identify individual weaned piglets at the meal trough (Zhu, 2021). Piglets' ears are tied to the H.F. tag. Within the circular trough of the feeder sat the circular high-frequency antenna (HFA). Multiple tags can be registered simultaneously using the anti-collision mechanism.

A video camera also monitors the animals' behaviour. Each time the animal enters the feeding area, a unique identification code is generated and sent to the server. This data can then be used for future registration and analysis. RFID system accuracy will be determined by comparing video observation data with RFID system data and measuring the time discrepancy for the RFID system. RFID-based livestock and tracking systems that improve beef quality and safety in China were created and evaluated (Zhu, 2021).

It has tools for raising cows, processing meat, and finding animals. The cattle breeding management system captured a variety of health parameters, including the animals' diets, vaccination histories, and immunisation records. The herd keeper used a P.D.A. to decipher the H.F. tags on the animals. (P.D.A.). Serial port data is kept in the database and then used to transport data to the PC. Examined for health, they undergo gruesome procedures, including bloodletting, peeling, and disembowelment. After that, the carcasses will undergo acid decomposition to remove the lactic acid and be packaged. In the slaughterhouse, the H.F. tags of the animals are read and copied into two tags.

These two RFID tags will be attached to each dyad when the animals are slaughtered and separated into pairs. The dyads will be broken up into tetrads, each with a copy of the H.F. tag added. In the next step of the process, the data from the H.F. tags are transferred to UHF RFID tags and affixed to the animal's segmentation for further analysis and research. Packages are labelled with 2D barcodes based on the information contained in the UHF tags. The animal's data can be retrieved through the system's retrieval section. These systems make use of HF RFID technology for animal identification.

Mabad et al. (2021) reported that solely HF RFID technology and sensors could be used to collect data on sows at the food trough. The technique can accurately identify multiple piglets. The tractability methods established for cattle and beef are comprehensive and practical (Williams, et al., 2019). Thus is a good option for those who prefer to read on the go. H.F. technology uses the exact inductive coupling mechanisms as L.F. technology to communicate with tags; however, they have a more excellent range and read speed than L.F. technology.

d. Ultra-High Frequency Radio Frequency Identification -Based Livestock Management System

Ultra-high-frequency radio-frequency identification (RFID) operates in the 860-930 MHz frequency range. All the components of the RFID poultry traceability system developed were incorporated (Lee, et al., 2019). Sensor, RFID tag, and RFID reader are part of the system's hardware.

The four types used are access cards, resealable cage tags, and user cards. Truck drivers use L.F. tags to record timestamps along the route. Trucks use the e-seal, a UHF tag with embedded numbers, to keep track of paperwork and license plates. The first tower light controls cars entering and exiting; the second light employs sensors to monitor traffic.

The project's software includes a web server, a database, and a system for transporting poultry. Tracking of vehicles and animals using poultry transportation management software can be done. The program automatically stores the results in the database as the truck and animal travel. The e-seal number can also be seen on the vehicle's license plate. A web service is used to transfer data across databases. The software includes a web service, a

database, and a UHF reader. An automatic UHF reader is activated when a vehicle passes by detection sensors at the checkpoint. The first tower light will turn green as soon as the reading begins. UHF readers then read the e-seal and cage tags affixed to the animals. The database's records were compared to the e-seal data. If the vehicle does not match, it will wait for more instructions. The movement data can also be shown on display. When a vehicle is authorized to pass the checkpoint, a second tower light will turn green, and a time stamp will show on the access card.

UHF RFID tags were used to track the birds in each cage (Gu & Black, 2020). Animals shipped to Hong Kong for testing and study were tagged using an RFID-based provenance system with UHF tags to boost public confidence. (Azmi, et al., 2019). Tracking animals from conception through slaughter is made possible by RFID readers, which store all of their collected data in a single location for later retrieval. Animal husbandry and feeding; farming procedures; sickness treatment; slaughter; vaccination; transportation; and veterinary care were among the many topics covered in this research developed an app to identify fattening pigs using UHF RFID technology (Gu & Black, 2020). Twelve pigs have different types of UHF tags connected to them. Additional UHF readers were placed in an alley of the feeding house to measure and analyse each recognition rate. Using an appropriate UHF tag and reader has been proven to increase the identification rate of this method.

Each application for a specific animal, such as chicken or beef, was discussed in depth (Barge et al., 2020). Floyd (2018) reported using UHF RFID technology to identify animals, while the rest used animal traceability systems. Even though the reading range of UHF technology is ten meters, it has several disadvantages, such as susceptibility to water and metals and privacy problems.

2.2.3 Benefits of Radio Frequency Identification Technology in the Management of Livestock

The adoption of RFID is defined by the number of benefits to be derived from it. According to Williams, *et al.,* (2019), RFID technology has been used in livestock identification, livestock traceability, automatic scanning and weighing, and automatic feeding.

Animal identification has been a pioneer in using RFID for about two decades (Duan, & Cao, 2020). RFID tags identify a specific animal in the following ways: An animal's collar can be attached to a transponder, or a transponder can be implanted in the animal's ear or subcutaneously (Adrion, 2020). For on-farm record-keeping and stock identification, RFID tags include serial numbers that facilitate the identification and management of the numbers of cattle stock.

Barge, et al. (2013) studied RFID technologies for livestock management and meat supply chain traceability in New Zealand. The experimental design was employed, and it was found that RFID technologies have been helpful in animal identification and tracking. Dogan, et al. (2016), a similar study on radio frequency identification systems in animal monitoring, established that RFID technologies have prevented theft and fraud.

Ibrahim, et al. (2016), the use of RFID in curtailing cattle rustling in Katsina State, Nigeria, also indicated that RFID use in identifying livestock has been beneficial in combatting cattle theft. However, the adoption of RFID technologies has been impacted by numerous factors. The study by Barge, et al. (2013) and Dogan, et al. (2016) did not indicate or explore the possible factors as they only dwell on using RFID. The proposed study, aside from exploring the benefits of RFID, also seeks to determine the factors that impact the adoption of RFID.

Adopting a literature-based approach, Gwaza and Gambo (2017) investigated the application of RFID technologies in the selection for genetic improvement of Rural livestock breeds in Nigeria. Gwaza and Gambo (2017) noted that data from RFID tags are accurate records in livestock management and facilitate the monitoring of cattle breeding activity, animal identification, sires, and dams of progenies. Likewise, a study by Singh (2020) on the application of RFID for dairy cattle management established that RFID had extended breeding and production management. However, the study did not indicate the factors that impact the adoption of RFID in livestock management.

RFID technology has also been used in animal traceability (Mengui, Oh & Lee, 2019). RFID technology has enormously traced livestock in the gracing field (Gomez et al., 2021). Investigating the role of RFID in the Agro-Food Sector in India, Kumar and Srivastava (2018) established that RFID is already being used in animal identification and tracking animals for traceability control. Also, Zhang, et al. (2017), investigating the application of RFID in the agricultural product industry, established that RFID has been essential in livestock traceability and cold chain monitoring. However, limited studies still focus on the factors that impact the adoption of RFID technology in livestock management.

Moreover, it is argued that RFID has been helpful in the automatic feed monitoring and rationing of food and water for livestock animals. Automated feeding procedures make it far easier for farm workers to keep track of the amount of feed given to each animal based on their previous productivity levels (Ula, et al., 2021). Additionally, self-regulated feeding ensures that animals are fed enough food while removing the possibility of human error. This method also saves much money because farms do not have to feed many cows who do not produce much milk. A study by Racewicz *et al.* (2021) on welfare health and productivity in commercial pig herds indicated that RFID had helped track pigs' feeding behaviour, linking

feeding information with the health and welfare of animals in intensive pig farming facilities. Similarly, Ruhil, et al. (2013), focusing on using RFID in managing livestock feeding programs, established that RFID facilitated controlled feeding of cows.

2.2.4 Summary of Frequency Performance

Table 2.4: Summary of RFID frequency performance

Low Frequency	**High Frequency**	**Ultra-High Frequency**
125-134 kHz)	13.56 MHz	860 to the 930MHz
Less absorption by moisture.	Less absorption by moisture.	Absorption by moisture is more.
Better Omni-directional capability.	Better Omni-directional capability.	High speeds
Less impact from metal	Less impact from metal	More interference from metal
Shorter signal range and Slower reading.	Shorter signal range and Slower reading.	Longer reading range.

2.3 Summary and Research Gap

In the chapter, a critical review of the literature regarding the use of RFID technology in livestock management. The critical review revolved around the benefits of Radio Frequency Identification technology in the management of livestock, factors that influence the implementation of Radio Frequency Identification technology in the management of livestock, and procedures and requirements in developing a radio frequency identification framework for managing livestock. In the chapter, theoretical models that anchor the study objectives were advanced. The relevance of the theories was explained and lined with the study objectives.

RFID technology has existed since the early 1970s, and no research has been completed on RFID deployment in cattle management. Regarding RFID adoption, researchers need to know how livestock producers can use it to its fullest potential. As a result, the study's goal is to propose RFID's use in cattle management. Moreover, limited empirical studies have focused on the use of RFID in livestock management by narrowing to cost against benefits of RFID and factors that influence the implementation of RFID. Available studies focused use of RFID in livestock management in advanced countries. Barge, et al. (2013) looked at RFID use in livestock management in Canada but did not indicate possible factors that affect the imp mentation of RFID. A study by Hossain and Quaddus (2019) investigated factors that affect the implementation of RFID in Australia and found that external environment, technological characteristics, and organisational factors are significant for RFID adoption.

Local studies like that by Ibrahim, et al (2016) focused on using RFID in taming cattle rustling in Nigeria. Likewise, Siror, et al. (2010) studied using RFID to combat cattle rustling in East Africa. Both Siror, et al. (2010) and Ibrahim, et al (2016) did not explore the cost against benefits of RFID in livestock management. Moreover, the studies did not explore

the factors that influence the implementation of RFID in livestock management. The study proposes a framework for implementing radio frequency identification in livestock management in Nyeri County, Kenya, focusing on RFID benefits and factors that influence its implementation.

Because of the low labour cost, the uneducated farmer is typically scared of being replaced by modern technology. Meanwhile, farm owners are less interested in modern technology. RFID has a critical role in bridging the digital divide in agricultural operations. Trailblazers in RFID investing will reap the most significant rewards and further expand the information and technological gap. Improved animal health and ease of management are all made possible by incorporating more readily available information. There are four main reasons why RFID is not widely used on farms: cost, standard, lack of understanding, and technology suitability. Researchers in the poultry industry are analysing how to narrow the digital divide to manage their farms better using RFID technology.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction to Research Methodology

This chapter focuses on the study's research methods. In addition to studying ideas, sampling processes, and research instruments, data analysis procedures are also included in the methodology. Qualitative and qualitative research methodologies were employed in this study. The two approaches complement one another by offering comprehensive statistical data and in-depth explanations and descriptions of the phenomenon under study (Bell, Harley & Bryman, 2022). The researcher employed a questionnaire and interviews to collect quantitative information.

3.2 Flow chart of the research methodology

Figure 3.1 shows the Flow chart of the research methodology. The objectives of the study guided the flow chart of the research methodology. The objectives of the study;

i. To identify the factors that influence the adoption of a Radio Frequency Identification Technology for livestock management among small-scale farmers in Nyeri County.
ii. To develop a Radio Frequency Identification framework for the management of livestock in Nyeri County, Kenya.
iii. To evaluate the Radio Frequency Identification Technology’s benefits in livestock management among small-scale farmers in Nyeri County.

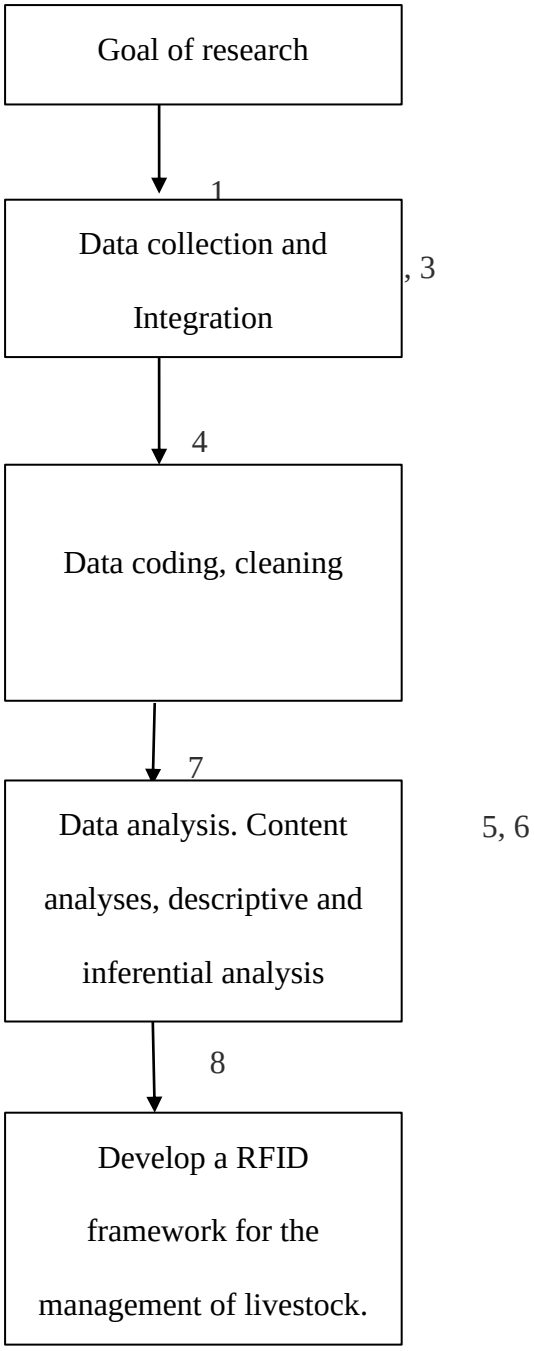


Figure 3.1: Methodology

3.3 Research Design

In this study, a contemporary mixed-method research design was employed. The study employs both quantitative and qualitative approaches in concurrent mixed-method research. This design involves a single study containing qualitative and quantitative data collection conducted simultaneously (Kroll & Neri, 2009). With this design, the researcher can triangulate findings from different data collection methods, enhancing the robustness and in-depth study findings. Thus through this research design, it is possible to evaluate the Radio Frequency Identification technology's benefits in the management of livestock among small-scale farmers, identify the factors that influence the adoption of radio frequency identification framework for livestock management among small-scale farmers, and develop a radio frequency identification framework for the management of livestock in Nyeri County Kenya by collecting information from smalls scale livestock farmers, interviewing the authorities in charge of livestock management and use of RFID technologies in livestock management.

3.4 Research Site

The research site was Nyeri County, located in the Kenyan highland. Nyeri County is one of the counties in Kenya located in Central Kenya. The county is between longitudes 36038' East and 37020' East and between the equator and latitude 00 380 south. It covers an area of 3,325 Km^2, according to the 2019 Kenya Population and Housing Census. It is divided into six constituencies: Kieni, Nyeri Town, Mukurweini, Mathira, Tetu, and Othaya. According to Nyeri Strategic Plan (2018-2023), 85 per cent of the population in Nyeri practice livestock farming as a form of livelihood.

Crop farming, livestock farming, and business enterprises are major economic activities in the region. Dairy cows, poultry, pigs, goats, donkeys, and sheep are some of the most

common livestock species in Nyeri County's traditional livestock production. 85% of the population is involved in dairy, sheep, goats, bees, rabbits, piggery, and poultry husbandry in the livestock sector. According to government estimates, Nyeri County, home to 176,000 dairy cows, produced nearly Ksh 4.3 billion animal products in 2017. livestock farming has a wide range of issues, including limited pasture and low-quality commercial feeds; animal infections; scarce field officers; high costs of inputs and poor marketing; and many more (Kigen & Ndegwa, 2021).

Due to the growing need to enhance livestock management through enhanced pasture management, identify and combat animal disease outbreaks, spread and food safety, and improve livestock identification and traceability in the international market, RFID has gained significant recognition in Nyeri County. Despite the prominence of RFID in livestock management in Nyeri County, many livestock farmers are not adequately aware of the cost-benefits associated with RFID in livestock management. In addition, proper deployment of RFID has been argued to be hindered by technology challenges, technical know-how of RFID, cost implications, and government regulation regarding the use of RFID. The map of the coverage area is seen in Appendix 4.

3.5 Target Population

The target population is an all-inclusive investigation arrangement of individuals, protests, or occasions that a researcher wishes to investigate and generalize (Clark & Watson, 2019). This research's target population comprised small-scale livestock farmers in Nyeri County, consisting of six constituencies: Kieni, Nyeri Town, Mukurweini, Mathira, Tetu, and Othaya. The study also targeted three agricultural officers from Nyeri County and an RFID expert (Managing director) from Idea Kenya Solutions.

Table 3.1: Target Population

Sub-county	Households	No. Livestock Farmers
Keini	64,454	30,720
Nyeri Town	28,228	18,432
Mukurweini	27,040	15,662
Mathira	54,064	36,480
Tetu	24,139	11,520
Othaya	49,945	34,560
Total	247,870	147,374

Kenya Population and Housing Census (2019) and Dairy Farmers Federation Nyeri Branch (2020).

3.6 Determination of Study Sample

3.6.1 Sampling Procedure

The sampling procedure is the process of picking an area of a population to participate in the study, allowing participants to choose to represent the population from which they were drawn rather than being selected randomly (Bodnar, et al., 2013). The target population was sampled using a stratified sampling method. Stratified random sampling was appropriate to include livestock farmers from the different sub-counties in Nyeri County, called strata. The sub-counties formed six (6) strata, each named Kieni, Nyeri Town, Mukurweini, Mathira Tetu, and Othaya. The stratified random sampling method is more precise, less biased, and less expensive than a random sample.

3.6.2 Study Sample Size

The sample size should be large enough for researchers to be confident that different examples of the same size drawn using the same procedures will yield roughly similar results. It is the size of the sample that causes sampling error to be more pronounced. Livestock farmers in Nyeri County were surveyed in order to collect representative data.

The study's sample was selected using a simple random sampling technique. When choosing a sample size, the most crucial consideration is how accurately the sample size reflects the population being studied. Since the population is more than 10,000, the sample size of the study was calculated using Fisher *et al.* (1998) formula, which is as follows, where is the standard normal deviate = 1.96 for a 95% level of significance, 50% is the prevalence rate from other studies, and 0.05 is the degree of accuracy. Therefore,

$$n = \frac{z^2 p(1-p)}{d^2}$$ Where:

n= sample size;

z= the table value for the level of confidence, 95% level of confidence (1.96)

d= margin of error (0.05)

p= proportion to be estimated, Israel (1992) recommends that if you do not know the value of p, then you should assume p=0.5

$$n = \frac{1.96^2 0.5(1-0.5)}{0.05^2} = 384$$ livestock farmers

In addition, proportional sampling ensures that the population is accurately represented. It entailed calculating the population proportions in each of the various congressional districts. Based on these percentages, a representative population sample was drawn (Andrade, 2020).

Thus, the no of the population in different Constituencies = No of livestock farmers in sub-counties/ Total No. of livestock farmers * sample size (384)

Table 3.2: Sampling frame

No	Sub county	Sample
1	Keini	80
2	Nyeri Town	48
3	Mukurweini	41
4	Mathira	95
5	Tetu	30
6	Othaya	90
	Total	384

The study's sample was selected using a simple random sampling technique. When choosing a sample size, the most crucial consideration is how accurately the sample size reflects the population being studied—selecting 384 small-scale livestock farmers from the table of sample selection (Appendix 5). Statistically, a sample of at least 30 is required for a generalization proposition (Ali & Haseeb, 2019).

3.7 Data Collection Measures

3.7.1 Data Collection of Instruments

Data collection involves obtaining evidence to support or disprove a claim (Sileyew, 2019). When it came to gathering data, this study relied on traditional approaches. Small-scale livestock farmers were asked to fill out questionnaires. Interviews were also conducted as a first step in gathering data for the study.

3.7.2 Questionnaires

According to Appendix 1, the dependent variable, a questionnaire, was employed in this study (Figure 1.2: Conceptual framework diagram). Self-administered printed polls were used. There were two sections to the questionnaires (A, B). Descriptive statistics were used to generate percentages, ratios, or frequencies in Section A of the investigation, which contained general information on the respondent. Section B was described using a Likert scale of five ordinal measurements of the agreement for each sentence (1, 2, 3, 4, and 5). The Likert scale is used when conducting a more extensive study since it produces better data distributions and is more accessible for participants to comprehend.

The questionnaires were distributed through drop and pick method. The questionnaire was accompanied by a cover letter introducing the researcher and the study's purpose, a letter of introduction from the university, and the research permit, acquired from the National Commission for Science, Technology, and Innovation. Ethical procedures were administered

in the questionnaires to increase the high response rate. The respondents were assured that the information was intended only for educational use.

3.7.3 Interviews

Face-to-face interviews were done with Nyeri County officers from the Department of Agriculture. The County officers from the Department of Agriculture sought consent to conduct interviews. The Department of Agriculture officers of the six sub-county offices set the interview venue and time. The interviews lasted anywhere from thirty to fifty minutes each. Prior consent was acquired from the interviewees to use a recording device, recognizing that note-taking could distract and distort their responses, so they did so before they began the interview. The recording of the dialogue did help to reduce the number of mistakes made while trying to remember and deduce the answers. To ensure the confidentiality of their interviews, each of the participants agreed to sign a confidentiality agreement. For data analysis, all interviewees received a copy of the transcripts of their recorded interviews, which were transcribed and summarized to form the foundation for data analysis. A mix of direct and inferred information was obtained from interviews with the interviewees.

3.8 Pilot Study

A pilot study was conducted in Kiambu County because the county has substantial livestock farming activities supported by RFID technologies. The final analysis did not include pilot study findings. However, a few observations were applied, and the following changes were implemented in the research:

1. Respondents indicated that the questionnaire was very lengthy and detailed.
2. Many of the responses had added an option for “Any other- Please specify” and “None from the selection.”

3.8.1 Instrument Reliability

The researcher used a Cronbach Alpha to ensure this; the questionnaire was first deployed in a pilot study, returning a Cronbach Alpha α coefficient of .87, surpassing the value of .7 (Patre, 2021).

Table 3.3: Reliability Statistics for the primary research instrument

Cronbach's Alpha	Cronbach's Alpha values	N of Items
Technological factors	.875	5
Cost implication factors	.727	5
Environmental and facility factors	.803	5
Data management factors	.914	5
Adoption of RFID technology	.768	7

Based on the reliability results above, technological, cost implication, environmental and facility factors and data management factors had Cronbach's Alpha more significant than 0.7. the statements for adopting RFID technology also attracted Cronbach's Alpha more significantly than 0.7. Based on this, the instrument was reliable.

3.8.2 Instrument Validity

People constructing measures are concerned with validity, while those looking for results are concerned with accurate scientific measurement. Validity is essential to any form or evaluation, and trustworthiness and accuracy are its foundation. According to Clark & Watson (2019), the degree to which empirical evidence and theoretical rationales support the sufficiency and appropriateness of interpretations and actions based on the questioner's scores is called validity. The researcher used content validation. "Content validity" is "the degree to which items in an instrument reflect the content universe to which the tool will be generalized (Bell, Harley & Bryman, 2022). The following are the steps required for validation:

- Extract related articles from specific literature review items.
- Content from the survey is compelled using a three-point scale to assess each item (not necessary, helpful but not essential, and essential).
- The expert on the survey finalizes content validation.
- Lawshe's (1975) method calculated each item's content validity ratio (CVR) (Baghestani, et al., 2019).
- Insignificant details were weeded out at the last minute.

The instrument's validity was ascertained through expert opinion in the industry and project supervisors. The experts in the RFID industry, livestock management using RFID, and the supervisor evaluated the questionnaire. Their review comments were used to enhance the validity of the instrument.

3.9 Data Collection Procedures

Before conducting the survey, the National Commission for Science, Technology, and Innovation (NACOSTI) approved the study to be conducted following the following research procedures. It was tested in a pilot study to guarantee that the data-gathering instrument was reliable and valid. To gauge a tool's efficacy, researchers examine how well it assesses the examined variables (Bell, Harley & Bryman, 2022). The study's validity was ensured by the help of the study's administrators—instruments for identifying and modifying questions and systems that are unclear, unmanageable, or unfriendly. Reliability is also supported when measuring the predictability of research tools. Respondents not part of the original survey were used to gauge the study's dependability. It was decided that the pilot test results would not be included in the final evaluation.

Data for this study was gathered via questionnaires provided to each participant. The study's objectives and methodologies were clearly explained to participants before they began the survey. The researcher made considerable effort to ensure that all participants returned their surveys to him. All questionnaires submitted and returned by the researcher were entered into an Excel spreadsheet. The census was conducted using a drop-and-pick-later method to ensure validity and reliability. The moderator aided in conducting in-person interviews during focus group discussions.

3.10 Data Processing and Analysis

Consistency and completeness from completed questionnaires were polished. Data analysis involved quantitative and qualitative analysis. Qualitative data collected via the interview guide was analyzed using the content analysis technique. The content analysis classifies sentences and explains their logic, Identifies relationships between words and concepts, and

the elocutionary power of words. The data were analyzed thematically, presented in narrative and prose, compared, and integrated with quantitative results to conclude.

To identify the factors that influence the adoption of a radio frequency identification technology for livestock management among small-scale farmers in Nyeri County.

Further, a multiple regression model was employed to determine the factors that influence the adoption of the radio frequency identification framework for livestock management among small-scale farmers in Nyeri County.

$$\mathbf{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e}$$

Where **Y**= adoption of radio frequency identification framework for livestock management among small-scale farmers.

Where:

$\boldsymbol{\beta_0}$= Constant

$\boldsymbol{\beta_{1, 2, 3, 4}}$ = Coefficient of X_1, X_2, X_3, X_4 and X_5

$\mathbf{X_{1\text{-}K}}$ = Independent variables are,

$\mathbf{X_1}$ = Technology factors

$\mathbf{X_2}$ = Cost factors

$\mathbf{X_3}$ = Environment factors

$\mathbf{X_4}$ = Expertise and knowledge factors

e = Error Term

$\boldsymbol{\beta_{1\text{-}4}}$ = The link between a dependent variable and a covariate is described using coefficients of variation (covariates) in a regression analysis.

This technique estimates a linear equation's coefficients and the dependent variable's independent variables. This model's coefficient of determination (R^2), correlation coefficient (R), and F-test at a 5% significance level were used to analyze the significance of the data reviewed.

For grounded theory, data is gathered through focus groups and interviews. Data coding is used in two stages to finish the operation. Coding began with creating a plethora of category codes for all systems. These ideas are compiled at this phase when the researcher attempts to find common themes and linkages frequently mentioned by the study project participants. With focused coding (step two), the researcher eliminates, consolidates, or divides the first step's coded groupings. Ideas repeatedly appearing in different codes suggested relationships (Bell, Harley & Bryman, 2022). This strategy can quantitatively compare focus group dynamics, individual participants, or the participants' remarks. Grouping data into categories helps find trends that would otherwise be missed by listening to or reading transcripts (Bell, Harley & Bryman, 2022).

To develop a radio frequency identification framework for the management of livestock in Nyeri County Kenya

The RFID framework for livestock management will be developed based on the study's results. The key metrics to be observed in livestock management in Nyeri County using RFID technologies include pasture control, disease outbreak, and water point management.

Equipment required:

1. Ear tag applicators
2. Ear tags
3. Crush or chute
4. Disinfectant

5. First aid kit
6. Nose restrainers
7. RFID Android handheld reader
8. The rCAPTURE mobile application,

The steps in developing the proposed RFID model framework for managing livestock in Nyeri County include the following.

Step 1: Restrain animal(s) in the crush or a chute with a head-gate

Step 2: Clean the applicator and tags to decrease the risk of infection

Step 3: Ensure the correct placement of male and female tags on the applicator

Step 4: Apply the tag on the left ear

Step 5: Enter the ear tag number and animal details into a register

Step 6. Upload the ear tag number and animal details into the LITS database

The RFID Infrastructure for the management of livestock in Nyeri County

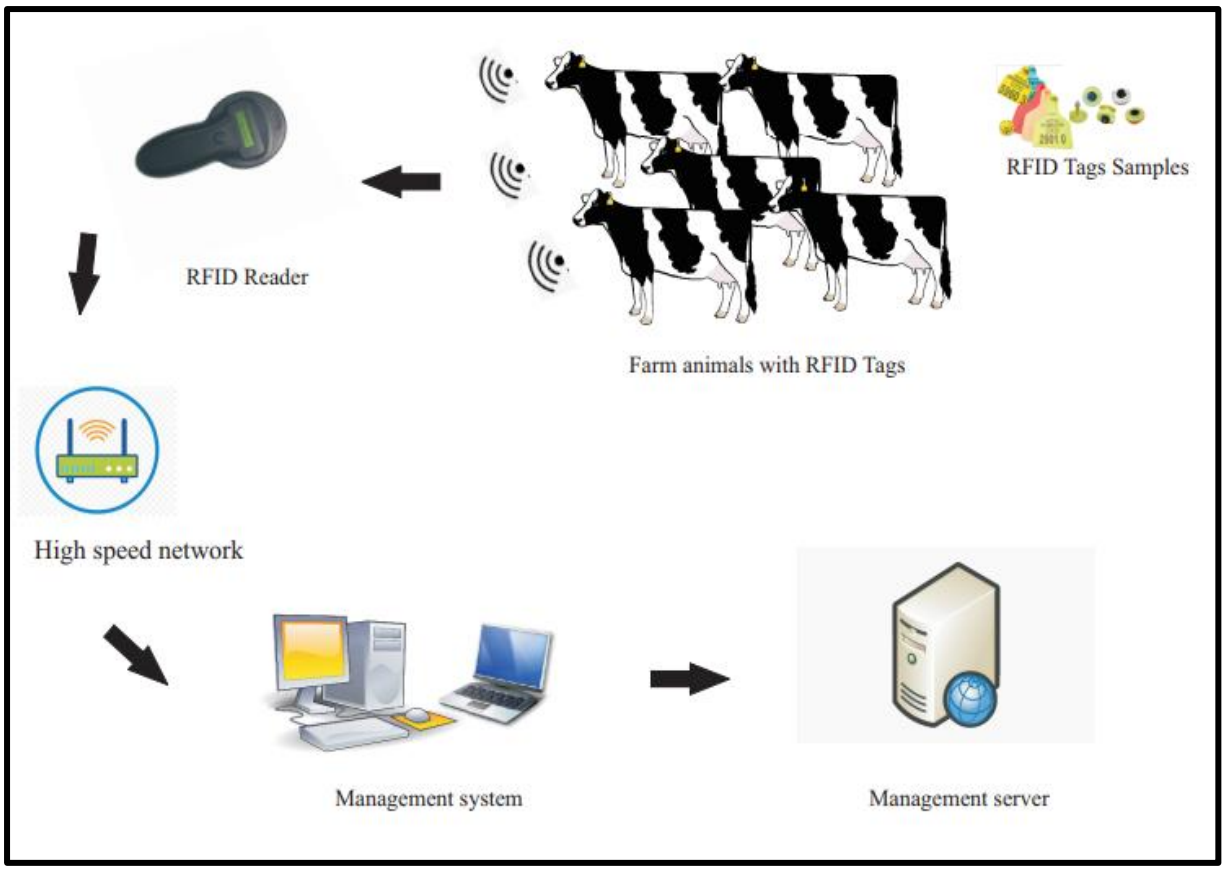


Figure 3.2: RFID model and infrastructure in Nyeri County

To evaluate the Radio Frequency Identification technology's benefits in livestock management among small-scale farmers in Nyeri County.

The quantitative data was then analyzed using descriptive statistics. The descriptive statistical tools (SPSS V.20.0) helped the researcher to describe the data. Descriptive statistics were employed to evaluate the Radio Frequency Identification technology's benefits in managing livestock among small-scale farmers in Nyeri County. The descriptive statistics include percentages, means, and standard deviation. The output was presented using tables.

3.11 Legal and Ethical Considerations

There were some ethical concerns with this study. The Ministry of Education's National Council for Science, Technology, and Innovation granted the researcher permission to conduct his research (NACOSTI). The researcher is always responsible for protecting the confidentiality and integrity of the research process.

CHAPTER FOUR

DATA ANALYSIS ANF FINDINGS

4.1 Introduction

This chapter represents the variables' findings and interpretation, including the response rate and descriptive statistics. Interpretation and discussion of findings were also undertaken in this chapter. The presentation of results was through tables, figures, and quotations.

4.2 Response Rate

The number of questionnaires administered was 317, and 384 were duly filled and returned. The results of the response rate are shown in Table 4.1. Of the 384 questionnaires administered, 317 were filled correctly and returned, representing an 82.6 per cent response rate. This response rate is considered satisfactory for making conclusions for the study. According to Bell, Harley, and Bryman (2022), this response rate was sufficient, representative, and consistent with their findings. To be considered suitable for analysis and reporting, a response rate of 50% is required, whereas a reasonable response rate of 82% or higher is required. Given this claim, the response rate 279 is exceptional (equal to 82.5%). This high participation rate may be attributable to the methods utilised for data gathering. These included pre-notification of respondents and voluntary participation by respondents; drop and pick of questionnaires to allow for ample time to fill; assurance of confidentiality and anonymity and follow-up calls to clarify queries from the respondents. All five Nyeri County agricultural officers participated in the interview session.

Table 4.1: Response Rate

Response	Frequency	Per cent
Returned	317	82.6%
Unreturned	67	17.4%
Total	384	100%

4.3 Demographic Information

4.3.1 Distribution of Respondents by Gender

Participants were asked to select a gender category when filling out the survey. The goal was to determine the participation of men and women in livestock management in Nyeri County. The results are depicted in Figure 4.1. Most respondents (67.8 per cent) were male, while 32.2 per cent were female, as shown in Figure 4.1. All responders, regardless of gender, were asked to participate in the survey. The results imply that most of the livestock farmers in Nyeri County were males, who were mostly the heads of the households.

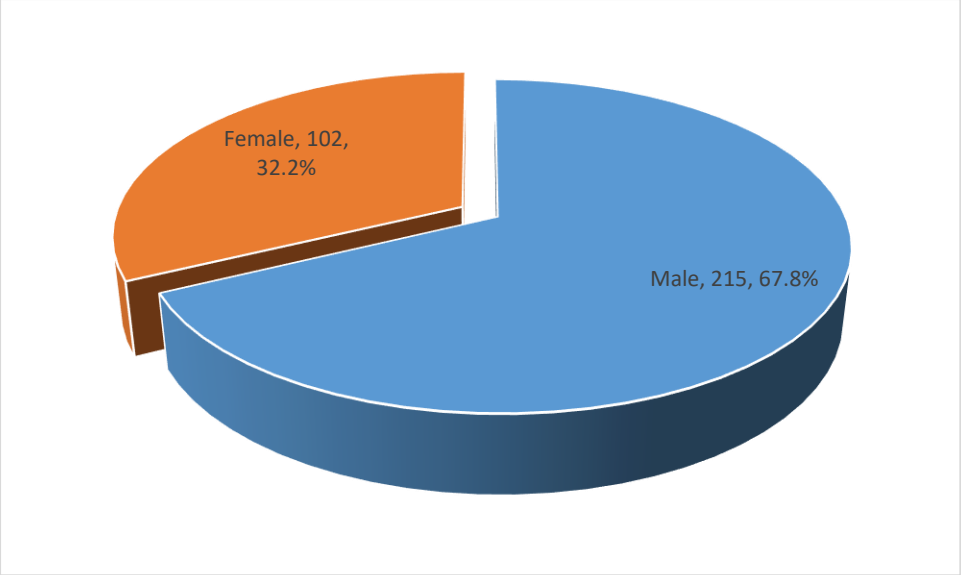


Figure 4.1: Gender of the respondents

4.3.2 Age Distribution of Survey Participants

Respondents of different ages are thought to have differing viewpoints on numerous topics; thus, the researcher asked them to declare their age category to get perspectives from these groups. The results of the study are shown in Figure 4.2. Results show that 45.1% of respondents were aged between 41-50 years, 30.3% between 31-40 years, 14.8% were above 50 years, and 9.8% were below 30 years. It is clear from the study's findings that participants of different ages were suitably involved in these investigations. The statistics also suggest that most livestock farmers are between the ages of 41 and 50.4.3.3 Education Background of the Respondents.

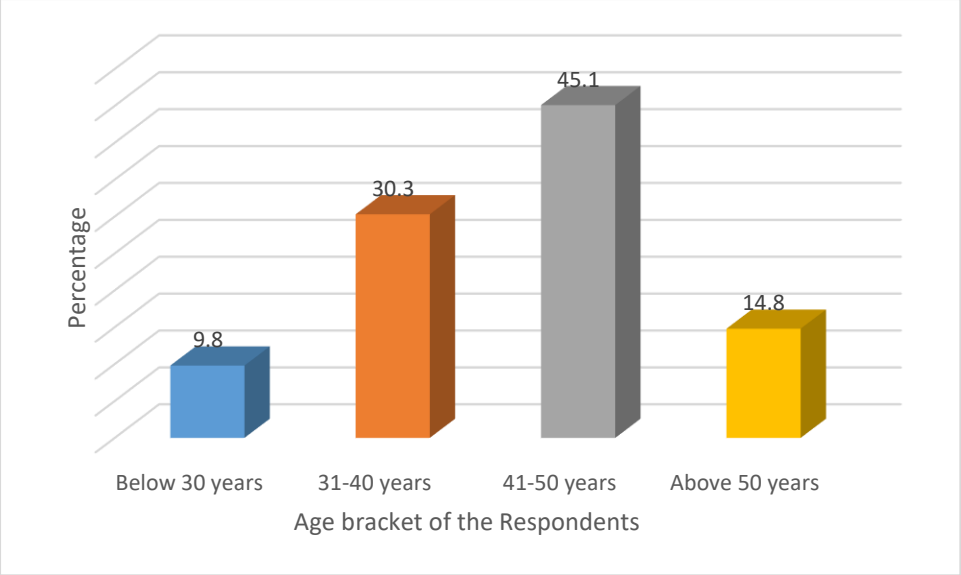


Figure 4.2: Age Distribution of Survey Participants

Respondents were required to indicate their highest educational qualifications. The level of education may inform the knowledge regarding proper livestock management practices. The results are shown in Figure 4.3. From that study findings, 40.1% of the respondents had attained a polytechnic level, 29.7% indicated that they had reached a secondary level, and 17.0% stated that they had achieved the university level. In comparison, 13.2% of the respondents indicated they had attained the primary level. That most respondents could read and write bodes well for the quality of responses to study questions. In addition, their level of education may influence farmers' ability to manage their animals effectively, which is essential for increasing output.

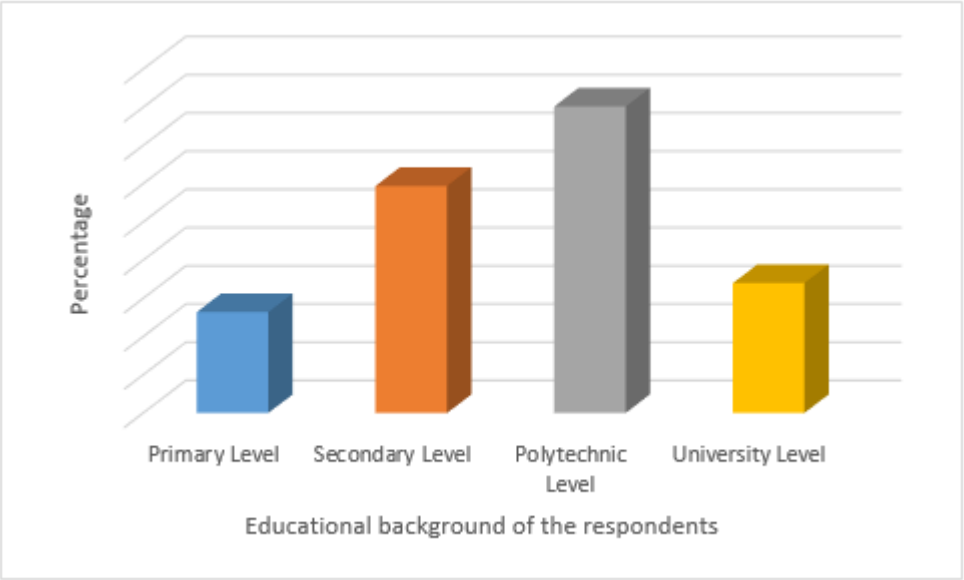


Figure 4.3: Education Background of the Respondents

4.3.4 Period in Which the Respondents Had Been Practising Livestock Farming

Participants were required to indicate the period they had been practising livestock farming. The results are shown in Figure 4.4. From the study findings, 42.0% of the respondents indicated that they had practised livestock farming for more than sixteen years, 34.7 % of the respondents stated that they had practised livestock farming for 11-15 years, while 13.9% of the respondents indicated that they had practised livestock farming for 6-10 years. Most of the respondents implied that they had practised livestock farming for a considerable period, which means that they were in a position to give credit information relating to this study.

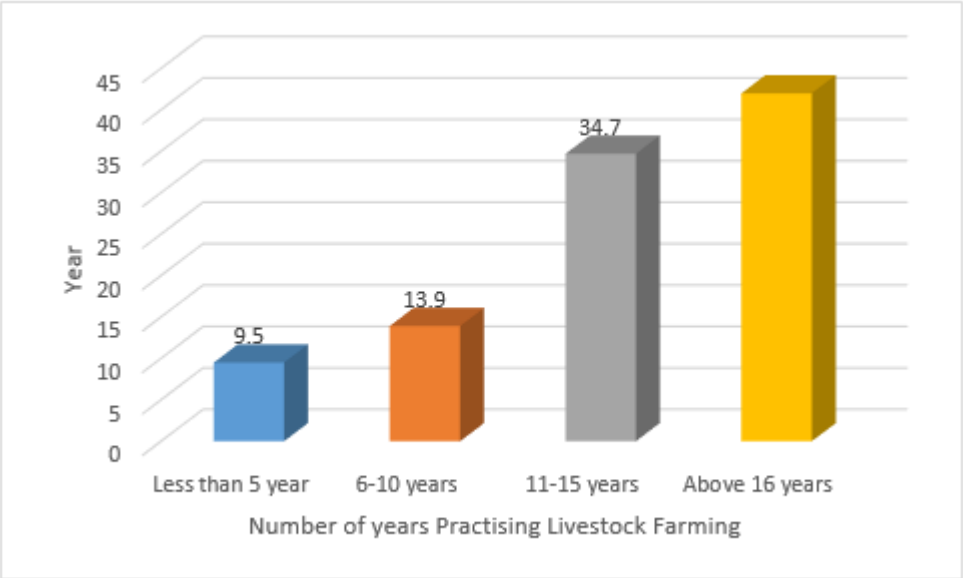


Figure 4.4: Number of years Practising Livestock Farming

4.3.5 Number of heads of cattle

The respondents were asked to indicate the number of livestock rear. The results are shown in Figure 4.5. It was established that 33.4% of the households reared a herd of 21-30 cattle, 20.2% reared cattle size of 11-20 cattle, and 18.9% had cattle size of more than 31 cattle. It was also established that 15.1% reared 6-10 cattle while 12.3% had five heads below cattle size. The results imply that cattle rearing is a significant economic activity in the regions, and thus enhanced livestock management through RFID is essential.

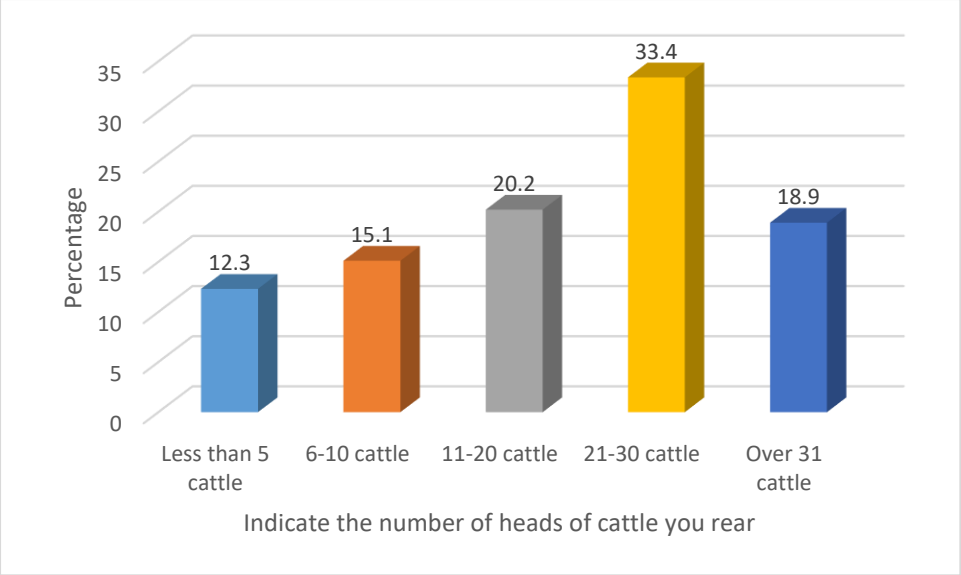


Figure 4.5: Number of heads of cattle

4.3.6 Size of land under cattle farming

Livestock farming requires sizeable tracks of pastureland. The respondents were asked to indicate the size of land under livestock. The results are shown in Figure 4.6. Most 42.3% of the livestock farmers reared cattle on ½ acre of land, 18.9% on a quarter, and 18.0% on 1-2 acres. It was also established that 14.5% reared cattle in an eighth of an acre while 6.3% reared cattle in over 5cres. The results imply that land in the study region is vital, and the land size is limited. Thus, pasture and water management using technologies like RFID are essential.

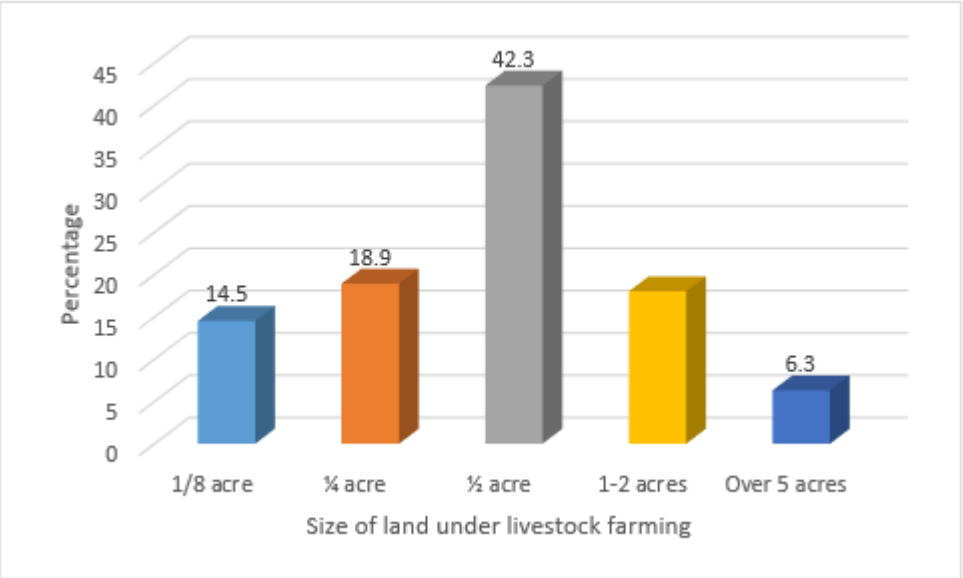


Figure 4.6: Size of land under cattle farming

4.3.7 Effectiveness of the Current Method of Livestock Farming

Participants were required to indicate whether the current livestock farming method is effective. Figure 4.7 presents the effectiveness of the current method of livestock farming. From the study findings, most respondents (56.4%) indicated that the current livestock farming method was ineffective, whereas 43.6% reported that the current livestock farming practice was valid. Most farmers in Nyeri County implied that the current livestock farming techniques are insufficient.

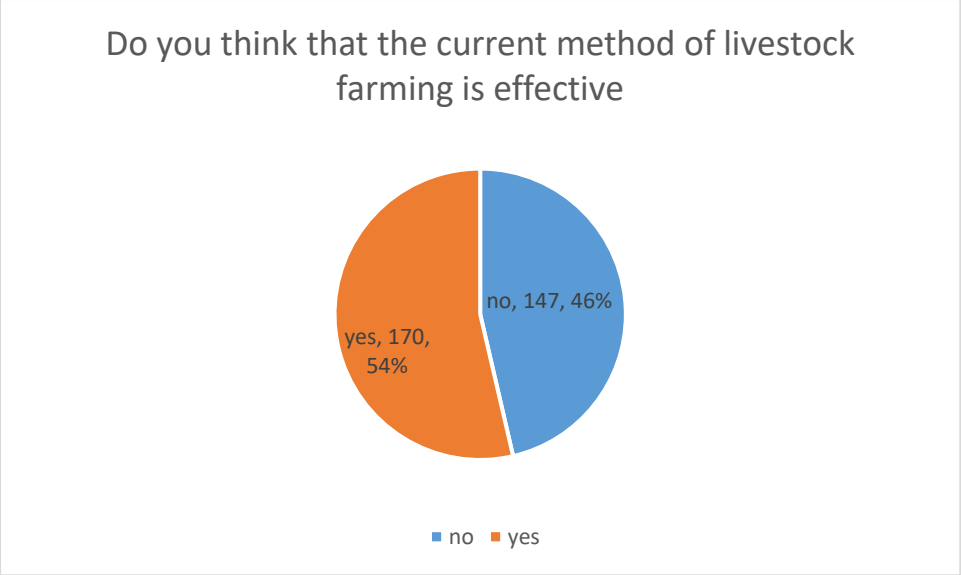


Figure 4.7: Effectiveness of the Current Method of Livestock Farming

4.3.8 ICT devices used by Farmers

The study sought to determine information communication and technologies. Figure 4.8 shows the ICT devices used by farmers. Results show that digital technology and other devices used by farmers include Smartphone android (52.6%), followed by smartphones (iPhone) (36.5%), tablets (26.3%), and computers (16.3%). In comparison, 6.7% of the respondents neither used the above ICT gadgets.

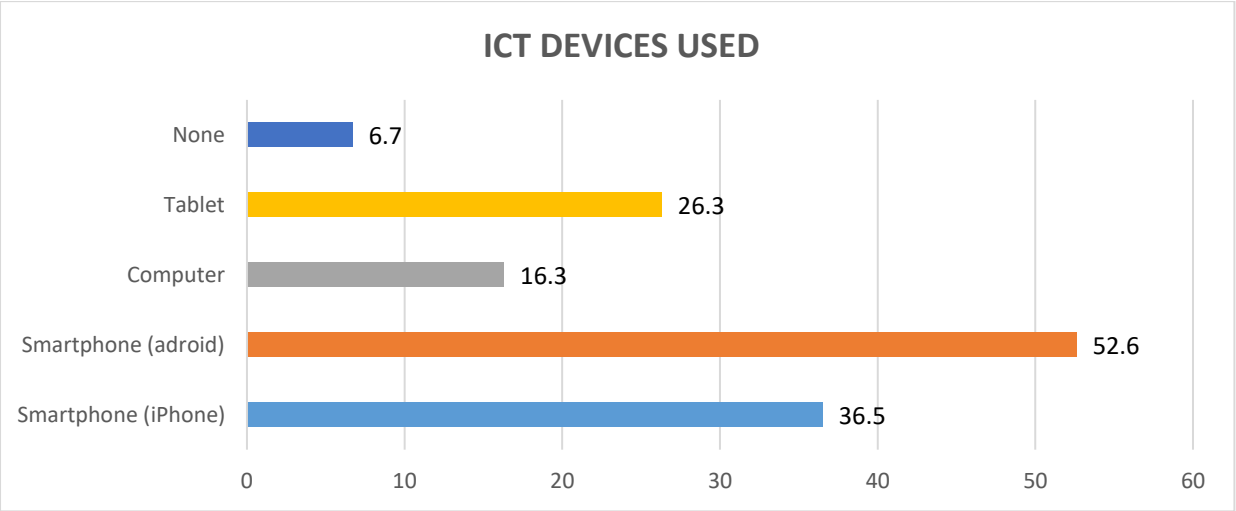


Figure 4.8: ICT devices used by farmers.

4.3.9 Duration Using RFID in the Management of Livestock

The study sought to determine how frequently livestock farmers have used RFID to manage livestock. Figure 4.9 Duration using RFID in the management of livestock. It was established that 32.5% of the livestock farmers had been using RFID in managing livestock for 3.6 years. It was established that 30.9% use RFID for 7-10 years, 19.2% for less than two years, and 17.4% for 11 years and above. The results imply that using RFID in livestock management has gained recognition in the study area.

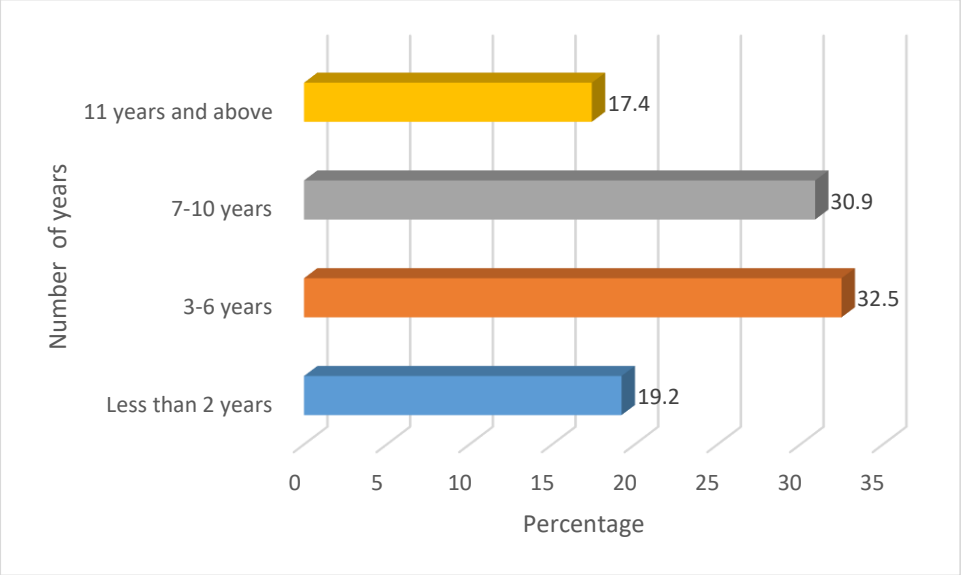


Figure 4.9: Duration using RFID in the management of livestock

4.3.10 Helpfulness of RFID in the Management of Livestock

The study sought to understand the helpfulness of RFID in livestock management. Figure 4.10 shows the responses**.** The study established that 45.1% of the respondents indicated that RFID has helped manage livestock, and 22.1% (very helpful). Further, 17.4% indicated that RFID is helpful, while 15.5% indicated that RFID does not help manage livestock. The

results imply that RFID has been very helpful in livestock management. RFID is used in managing cattle water points and pastures.

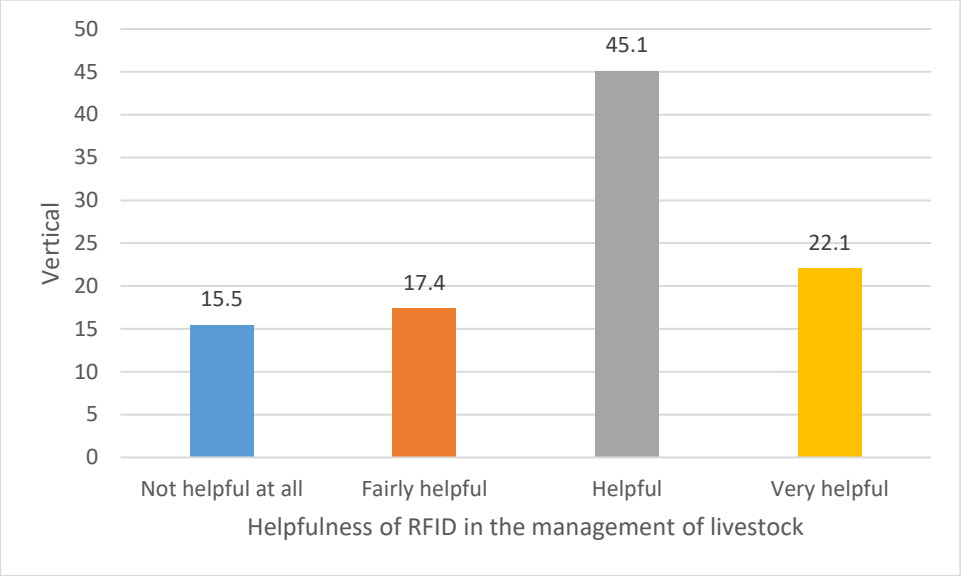


Figure 4.10: Helpfulness of RFID in the management of livestock

4.3.11 Farmer's Knowledge of IT Utilization

The study indicates whether the farmers have sufficient knowledge of information technology. Knowledge of information technology is helpful in the use of RFID. The results are shown in Figure 4.11. From the findings, 47.1% of respondents indicated that they had shared knowledge of IT, 43.9% of the respondents stated that they had an immense experience of IT, and 9.0% of the respondents indicated that they had low awareness of IT; this implies that most of the respondents had common knowledge on ICT utilization.

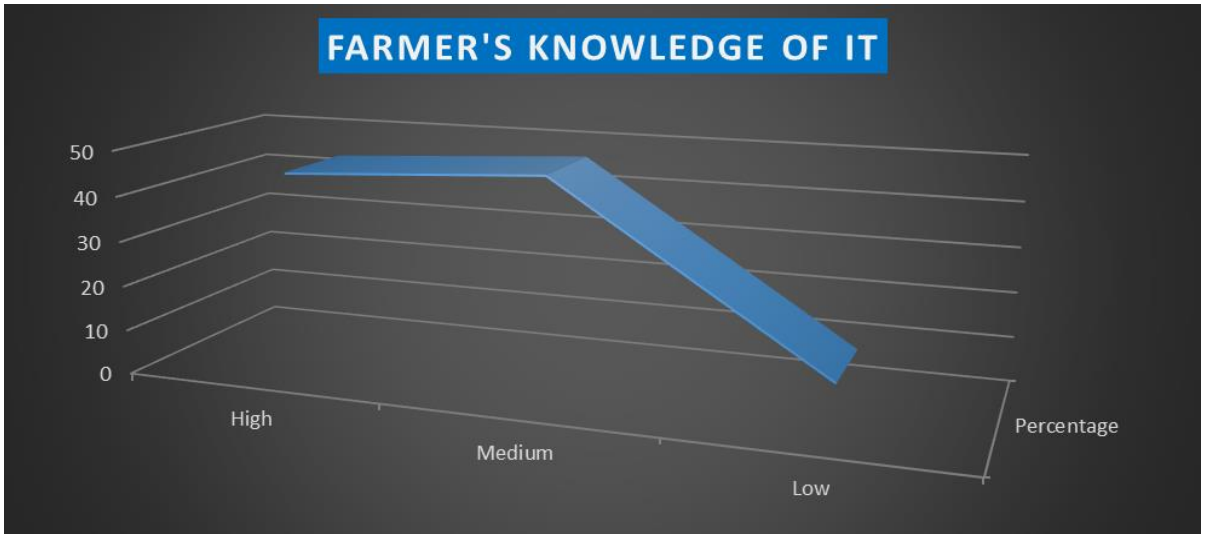


Figure 4.11: Farmer's knowledge of IT utilization

4.4 Benefits of Implementing Radio Frequency Identification Technology in the Management of Livestock

It is perceived that RFID technologies have brought certain benefits to the management of livestock. The study sought to investigate the benefits livestock farmers have accrued in using RFID in livestock management using descriptive results. The descriptive results employed include percentages, mean, and standard deviation. The results are shown in Table 4.2.

The descriptive results showed that most livestock farmers agreed that using RFID technology enabled them to improve livestock production and reduce costs. This assertion is supported by a mean response of 3.57 and a standard deviation 1.06. The standard deviation of 1.06 implies that the responses were clustered around the mean response. It was also found that most livestock farmers agreed that using RFID technology had enabled them to enhance the livestock's security and traceability, as supported by a mean of 3.52 and a standard deviation of 1.07. Further, the descriptive result revealed that the RFID technology had enabled the generation of timely, accurate, and granular data helpful in livestock management, as indicated by a mean response of 3.50 and a standard deviation of 1.07.

Moreover, it was established that the RFID technology has livestock farmers enhance the livestock feeding schedule and rationing monitoring. Given this, we can conclude that the mean response was 3.50, and the standard deviation was 1.11.

Automated livestock monitoring has improved, resulting in few labourers, as indicated by a mean of 3.54 and a standard deviation of 1.10. Descriptive findings indicated that with RFID, the livestock farmers in the study area have been able to properly trace and identify the livestock in the field, as indicated by a mean of 3.53 and a standard deviation of 1.10. Finally, the RFID has allowed livestock farmers to properly manage livestock feeding programs, as shown by a mean response of 3.55 and a standard deviation of 1.07. As per the results above, the aggregate mean was 3.53 and a standard deviation of 1.08. The aggregate mean of 3.53 implied that most livestock farmers agreed that RFID technologies had brought certain benefits in livestock management.

Table 4.2: Benefits of Implementing Radio Frequency Identification Technology in the Management of Livestock

Benefits of RFID in livestock management	SD	D	N	A	SA	Mean	STD
With the use of RFID technology, I have been able to improve livestock production and reduce the cost	8.2%	7.6%	15.1%	57.1%	12.0%	3.57	1.06
With the use of RFID technology, I have been able to enhance the security and traceability of the livestock	7.9%	9.8%	15.5%	56.2%	10.7%	3.52	1.07
The RFID technology has enabled the generation of timely, accurate, and granular data on the livestock on the farm	8.2%	8.5%	17.0%	57.4%	8.8%	3.50	1.05
The RFID technology has enabled me to enhance the monitoring of the livestock feeding schedule and rationing	9.5%	10.1%	11.4%	58.7%	10.4%	3.50	1.11
There has been improved monitoring of the livestock management of automation hence leading to few labourers	9.1%	8.8%	12.6%	57.7%	11.7%	3.54	1.10

With the use of RFID, I have been able to trace and identify the livestock in the field	10.4%	7.3%	10.4%	62.5%	9.5%	3.53	1.10
The RFID has allowed the farmer to manage the feeding programme of my livestock properly	8.8%	7.9%	13.9%	58.7%	10.7%	3.55	1.07
Aggregate mean/STD						**3.53**	**1.08**

Where SD is Strongly Disagree, D is Disagree, N is Neutral, A is Agree, SA is Strongly Agree, and STD is the standard deviation.

4.5 Factors influencing the adoption of RFID Technology for livestock management among small-scale farmers.

The study sought to identify the factors that influence the adoption of a Radio Frequency Identification Technology for livestock management among small-scale farmers in Nyeri County. Various factors were assessed, including technology-related, cost implications, environment and facility factors, and data management factors. Descriptive results were employed, including percentages, mean and standard deviation.

4.5.1 Technology factors

The study sought to investigate the technological factors influencing small-scale farmers' adoption of RFID technologies in livestock management in Nyeri County. Percentages, mean, and standard deviations were used to examine the data. The results are shown in Table 4.3.

The majority of the livestock farmers agreed that the acquisition of appropriate RFID technologies is a problem for them. A mean response of 3.68 and a standard deviation of 1.15 are consistent. It was also established that using RFID technologies in managing livestock was a problem for most small-scale livestock farmers in Nyeri County, as depicted by a mean response of 3.53 and a standard deviation of 1.26. Further, most farmers agreed that maintaining RFID equipment is a significant problem because they are not very well conversant with RFIDA mean response of 3.68 and a standard deviation of 1.15 are consistent.

The majority of the livestock farmers in the study area identified mechanical damage of RFID due to electromagnetic fields, and nearby electrical equipment was identified by the majority of the livestock farmers in the study area, as shown by a mean of 3.59 and a standard deviation of 1.22. Further, most livestock farmers acknowledged that tag collision and failure of tags undermine RFID technologies' effectiveness in livestock management, as shown by a mean of 3.51 and a standard deviation of 1.22. The aggregate mean response was 3.56, and the standard deviation of 1.17. The aggregate mean of 3.56 implies that most livestock farmers agreed that technological-related factors influenced the adoption of RFID for livestock management.

Table 4.3: Technology factors in the adoption of RFID

Technology factors	SD	D	N	A	SA	Mean	STD
The acquisition of appropriate RFID technologies is a problem for me	9.1%	10.1%	2.5%	60.6%	17.7%	3.68	1.15
The deployment and use of RFID technologies in the management of my livestock	12.3%	11.7%	5.0%	53.0%	18.0%	3.53	1.26
Maintaining RFID equipment is a significant problem because I am not very conversant.	10.7%	13.2%	8.5%	49.2%	18.3%	3.51	1.24
Mechanical damage of RFID as a result of electromagnetic fields and nearby electrical equipment	9.5%	13.2%	6.3%	50.5%	20.5%	3.59	1.22
Tag collision and failure of tags undermining the effectiveness of RFID technologies in livestock management	11.0%	11.7%	9.8%	50.2%	17.4%	3.51	1.22
Aggregate mean/STD						**3.56**	**1.17**

Where SD is Strongly Disagree, D is Disagree, N is Neutral, A is Agree, SA is Strongly Agree, and STD is the standard deviation.

4.5.2 Cost Implication Factors in the Adoption of RFID

The cost implication factors influencing the adoption of RFID technologies in livestock management by small-scale farmers in Nyeri County were investigated. Percentages, mean, and standard deviations were used to examine the data. Table 4.4 displays the obtained outcomes.

Most livestock farmers agreed that the cost of purchasing RFID tools is exorbitantly high. A mean response of 3.56 and a standard deviation of 1.29 lend credence to this. With a mean response of 3.51 and a standard deviation of 1.22, we also see that the cost of adopting RFID is within reach of deployment for the vast majority of small-scale livestock farmers in Nyeri County. The average farmer's answer was 3.56, with a standard variation of 1.25, indicating that they agreed with the cost of maintaining and replacing RFID implements in the event of damage or loss in the grazing area.

Most small-scale livestock farmers believe the cost of complying with privacy guidelines is associated with using RFID technologies, as shown by a mean of 3.50 and a standard deviation of 1.26. Furthermore, most livestock farmers agreed that the cost of managing health issues associated with using RFID technologies affected cattle management, as shown by a mean of 3.50 and a standard deviation of 1.18. The aggregate mean of 3.50 signifies that most livestock farmers agreed that cost implication factors influenced the adoption of RFID for livestock management.

Table 4.4: Cost Implication Factors in the Adoption of RFID

	SD	D	N	A	SA	Mean	STD
The cost of purchasing RFID tools is exorbitantly high	10.7%	14.8%	6.0%	45.1%	23.3%	3.56	1.29
Farmers find the cost of implementing RFID to be way my abilities	9.8%	14.8%	7.3%	50.8%	17.4%	3.51	1.22
The cost of maintaining and replacing RFID tools in case of damage or they are lost in the grazing field	10.1%	13.9%	7.9%	46.4%	21.8%	3.56	1.25
The cost of complying with privacy guidelines associated with the use of RFID technologies	10.4%	15.1%	8.5%	45.7%	20.2%	3.50	1.26
The cost of managing health issues associated with the use of RFID technologies in the management of cattle	9.8%	13.6%	7.6%	54.6%	14.5%	3.50	1.18
Aggregate mean/STD						**3.50**	**1.19**

Where SD is Strongly Disagree, D is Disagree, N is Neutral, A is Agree, SA is Strongly Agree, and STD is the standard deviation.

4.5.3 Environment and facility factors in the Adoption of RFID

The study sought to investigate the environmental and facility factors that influence small-scale farmers' adoption of RFID technologies in livestock management in Nyeri County. Percentages, mean, and standard deviations were used to examine the data. Table 4.5 displays the obtained outcomes.

Most livestock farmers agreed that plant canopy is a problem deploying RFID in livestock management. The data (mean response of 3.8, the standard deviation of 0.99) backs this up. In addition, a mean response of 3.76 and a standard deviation of 1.02 show that most small-scale livestock producers in Nyeri County agree that moisture content and precipitation frequently harm the livestock traceability tags. Most farmers agreed that temperature swings hinder the effectiveness of RFID livestock tags (mean response of 3.79 and standard deviation of 1.05).

Moreover, most livestock farmers in the study area identified moisture interfering with the transmission of RFID signals between tags and readers; a mean of 3.74 and a standard deviation of 1.05 back this up. Using a mean of 3.75 and a standard deviation of 1.07, the farmers showed that naturally occurring metallic particles in the ground and the area could reflect RFID signals. The mean total score was 3.71, and the std dev was 1.17. The median of 3.71 indicates that most farmers in Nyeri County who keep livestock agreed that infrastructure and surrounding conditions influenced using RFID for livestock management.

Table 4.5: Environment and facility factors in the Adoption of RFID

Environment and facility factors	SD	D	N	A	SA	Mean	STD
Plant canopy is a problem in the deployment of RFID in the management of livestock	1.9%	12.3%	9.1%	51.7%	24.9%	3.85	0.99
Moisture content and precipitation often damage the livestock traceability tags	3.2%	12.9%	8.5%	55.2%	20.2%	3.76	1.02
The variability of temperature ranges impacts the proper operations of the RFID tags in livestock	5.0%	10.1%	7.6%	55.5%	21.8%	3.79	1.05
Moisture interfering with the transmission of RFID signals between tags and readers	3.8%	13.6%	8.2%	53.9%	20.5%	3.74	1.05
The deflection of RFID signals by natural metallic material beneath the earth and surrounding	5.7%	10.1%	8.2%	55.8%	20.2%	3.75	1.07
Aggregate mean/STD						**3.71**	**1.04**

Where SD is Strongly Disagree, D is Disagree, N is Neutral, A is Agree, SA is Strongly Agree, and STD is the standard deviation.

4.5.4 Data management factors in the Adoption of RFID

The study sought to investigate the data management factors influencing small-scale farmers' adoption of RFID technologies in livestock management in Nyeri County. Percentages, mean, and standard deviations were used to examine the data. Table 4.6 displays the obtained data.

It was agreed by a majority of small-scale livestock farmers that related data privacy issues in the use of RFID impact the adoption of RFID, as shown by a mean response of 3.80 and a standard deviation of 0.99. Also, storing RFID data proved a problem for most small-scale livestock farmers (mean response of 3.73 and standard deviation of 1.05). Further, a significant number of small-scale livestock farmers in the study area agreed that the regulations guiding the use of RFID data influenced the adoption of RFID for livestock management. A mean answer of 3.79 and a standard deviation of 0.96 corroborate this conclusion.

Large amounts of RFID data and data integration across many facilities present livestock farmers with challenges in RFID data management (mean response of 3.79 and standard deviation of 1.00) and data management that affect RFID technology adoption in livestock farming (mean 3.72 and standard deviation 1.01). The aggregate mean response was 3.70, with and standard deviation of 1.02. The aggregate mean of 3.70 implies that most livestock farmers agreed that data management factors influenced the adoption of RFID for livestock management in Nyeri County.

Table 4.6: Data management factors in the adoption of RFID

Data management factors	SD	D	N	A	SA	Mean	STD
Related data privacy issues in the use of RFID	2.2%	12.9%	9.1%	54.3%	21.5%	3.80	0.99
The storage of RFID data	4.4%	12.9%	6.9%	56.5%	19.2%	3.73	1.05
Regulations guiding the use of RFID data	2.5%	11.7%	7.9%	59.6%	18.3%	3.79	0.96
Large amounts of RFID data and data integration across numerous facilities provide farmers with hurdles in RFID data management	4.4%	9.8%	6.6%	61.2%	18.0%	3.79	1.00
Data management that affects the adoption of RFID technology in livestock farming	2.8%	14.5%	8.2%	56.5%	18.0%	3.72	1.01
Aggregate mean/STD						**3.70**	**1.02**

Where SD is Strongly Disagree, D is Disagree, N is Neutral, A is Agree, SA is Strongly Agree, and STD is the standard deviation.

The study used structural equation modelling (SEM) to determine the effects of technology-related factors, cost implications, environment and facility factors, and data management factors on implementing a radio frequency identification framework for livestock management among small-scale farmers in Nyeri County. The SEM equation was estimated by conducting a composite mean response of adoption of RFID as the dependent variable; individual composite means response of technology-related factors, cost implications factors, environment and facility factors, and data management factors. The SEM equation results are shown in Figure 4.12 and Table 4.7.

Based on the SEM equation in Figure 4.12, technology factors positively influenced the adoption of RFID for livestock management in Nyeri County (β=.414), followed by environment and facility factors (β=.343). Data management had the most negligible positive influence on implementing RFID for livestock management in Nyeri County (β=.240). It was also established that cost implication factors negatively influenced the adoption of RFID for livestock management in Nyeri County, as indicated by a regression coefficient of -.151.

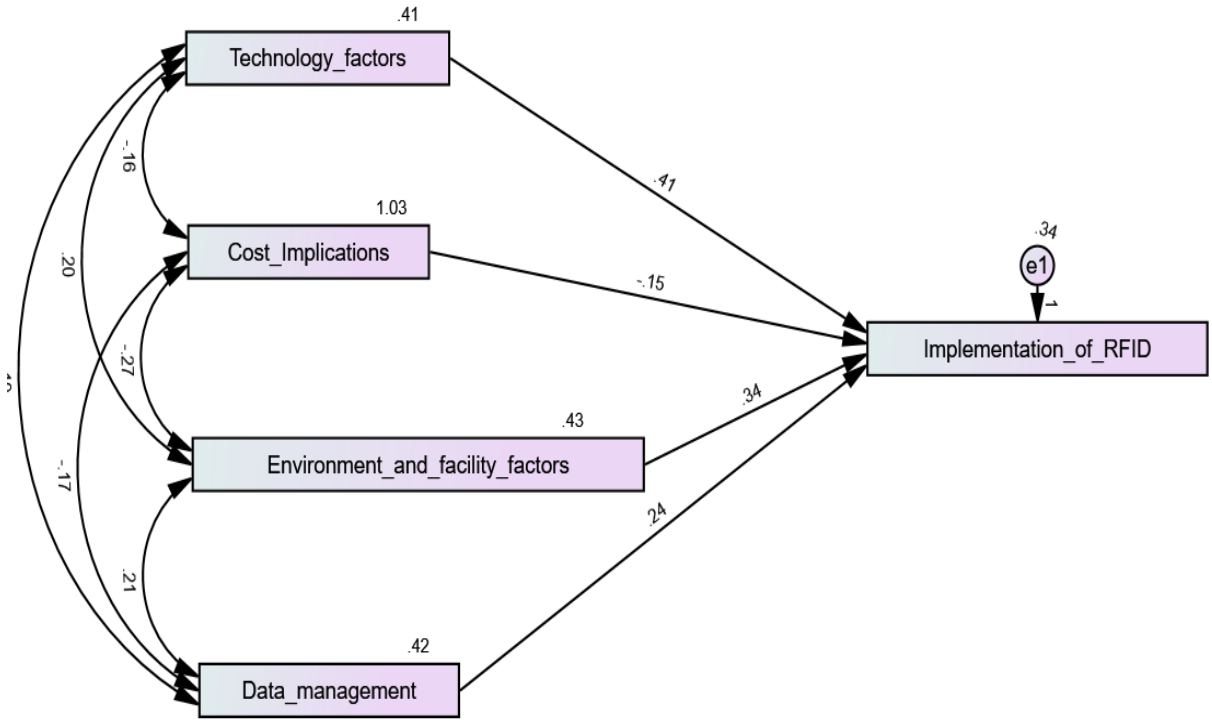


Figure 4.12: Structural Equation Modelling of Factors that Influence the Adoption of RFID in the Management of Livestock.

The comprehensive SEM equation with regression coefficients **s**quared multiple correlations and calculated p-values are shown in Table 4.7. The SEM results in Table 4.7 show that technology-related factors, cost implications, environment and facility factors, and data management factors adequately explained implementing the radio frequency identification framework for livestock management among small-scale farmers in Nyeri County. This fact is supported by squared multiple correlations of .512.

A negative and statistically significant relationship was found between the coefficient of cost implications factors and the adoption of RFID framework for livestock management among small-scale farmers (β=-.151, p=000<0.05). Based on the coefficient results, a one-unit rise in the cost implications factors resulted in a decline in implementing the RFID framework for livestock management among small-scale farmers in Nyeri County by 0.151 units. The study

rejects the null hypothesis and concludes that cost implication factors significantly influence the adoption of a Radio Frequency Identification Technology for livestock management among small-scale farmers in Nyeri County.

It was further established that the environment and facility factors coefficient had a positive and statistically significant relationship with implementing the RFID framework for livestock management among small-scale farmers (β=.343, p-value=.000<0.05). The SEM coefficient implies that a one-unit change in environment and facility factors resulted in .343 units increase in implementing the RFID framework for livestock management among small-scale farmers in Nyeri County. The study rejects the null hypothesis and concludes that environmental and facility factors significantly influence the adoption of a Radio Frequency Identification Technology for livestock management among small-scale farmers in Nyeri County.

Likewise, the coefficient of data management factors had a positive and statistically significant relationship with implementing the RFID framework for livestock management among small-scale farmers (β=.240, p-value=.000<0.05). The results imply that a one-unit improvement in data management factors results in .240 units increase in the implementation of RFID framework for livestock management among small-scale farmers in Nyeri County. The study rejects the null hypothesis and concludes that data management factors significantly influence the adoption of a Radio Frequency Identification Technology for livestock management among small-scale farmers in Nyeri County.

The technology factors positively and significantly influence the adoption of the RFID framework for livestock management among small-scale farmers (β=.414, p-value=.000<0.05). The results imply that a one-unit change in technology factors results in .414 units increase in adopting the RFID framework for livestock management among small-

scale farmers in Nyeri County. The study rejects the null hypothesis and concludes that technology-related factors significantly influence the adoption of a Radio Frequency Identification Technology for livestock management among small-scale farmers in Nyeri County.

Table 4.7: Structural Equation Modelling of Factors that Influence the Implementation of RFID in the Management of Livestock.

			Estimate	S.E.	C.R.	P-value
Adoption of RFID for livestock management	<---	Cost Implications	-.151	.036	-4.244	***
Adoption of RFID for livestock management	<---	Environment and facility factors	.343	.064	5.340	***
Adoption of RFID for livestock management	<---	Data management	.240	.060	3.987	***
Adoption of RFID for livestock management	<---	Technology factors	.414	.061	6.739	***
		Estimate				
Squared multiple correlations		.512				

*** sig at 1%,5% and 10%

4.6 Adoption of Radio Frequency Identification Technology for livestock management among small-scale farmers

The study sought to investigate how small-scale livestock farmers have deployed RFID livestock management among small-scale farmers. The results are shown in Figure 4.8.

A majority agreed that small-scale livestock farmers deployed RFID in animal identification, as shown by a mean response of 3.68 and a standard deviation of 1.16. Small-scale farmers use RFID ear tags or implants to uniquely identify each animal in their livestock. These tags contain an RFID transponder that stores a unique identification number. Farmers can quickly scan the tags using handheld or stationary RFID readers to identify and track individual animals.

Also, the RFID enables automated data collection (mean response of 3.70 and standard deviation of 1.12). RFID technology enables small-scale farmers to automate data collection processes. By setting up RFID readers at various points within the farm, such as water troughs or feeding areas, farmers can gather data on animal movements, feeding habits, and health indicators without manual intervention. This information can assist in making informed decisions about animal management and health.

Further, most small-scale livestock farmers agreed that using RFID had helped in herd inventory management, as indicated by a mean response of 3.60 and a standard deviation of 1.14. RFID tags enable small-scale farmers to maintain accurate and up-to-date livestock inventories. Farmers can quickly identify missing or lost animals by scanning the RFID tags periodically, tracking birth rates, monitoring growth rates, and recording other relevant data. This information aids in financial planning, breeding decisions, and overall herd management.

Moreover, RFID adoption facilitated proper livestock disease and health management (mean response of 3.53 and standard deviation of 1.23). The RFID technology can assist small-scale farmers in monitoring the health of their livestock. By using RFID-enabled monitoring devices, such as temperature sensors or activity trackers, farmers can detect abnormalities or signs of illness in individual animals. The collected data can help farmers identify potential health issues early, enabling timely intervention and reducing the risk of disease outbreaks within the herd.

The use of RFID to identify livestock at the grazing management also featured, as indicated by a mean of 3.62 and a standard deviation of 1.19. For farmers practising rotational grazing, RFID technology can be instrumental in managing grazing patterns. By setting up RFID readers at pasture gates or water sources, farmers can track when animals enter or exit

specific areas. This information allows them to optimize grazing rotation, prevent overgrazing, and manage pasture resources efficiently.

RFID adoption facilitated the use of RFID in recordkeeping and livestock traceability (mean response of 3.51 and standard deviation of 1.25). RFID technology simplifies recordkeeping and enhances traceability for small-scale farmers. Farmers can maintain comprehensive records of each animal's history, including vaccination records, breeding information, and any treatments administered by integrating RFID data with digital management systems or software. This information is invaluable for meeting regulatory requirements, ensuring food safety, and enhancing transparency in the supply chain.

Also, RFID has been essential in identifying market opportunities (mean response of 3.52 and standard deviation of 1.18). Adopting RFID livestock management systems can open up market opportunities for small-scale farmers. Some consumers prioritize knowing the origin and quality of their food products. By implementing RFID technology, farmers can provide traceability information to consumers, demonstrating that their animals were raised under certain conditions, received appropriate vaccinations, or followed specific feeding practices. This level of transparency can help farmers differentiate their products and access niche markets.

The aggregate mean of 3.70 implies that most livestock farmers agreed that implementing RFID had brought some benefits related to effective livestock management in Nyeri County. It is important to note that implementing RFID livestock management systems may involve initial costs for purchasing RFID tags, readers, and associated infrastructure. Additionally, farmers must invest time and effort into training and adapting their management practices to leverage RFID technology's benefits effectively. However, the long-term advantages of

improved efficiency, productivity, and animal welfare make RFID a viable option for small-scale livestock farmers.

Table 4.8: Adoption of Radio Frequency Identification Technology for livestock management among small-scale farmers

	SD	D	N	A	SA	Mean	STD
Animal Identification	7.3%	12.3%	7.9%	50.5%	22.1%	3.68	1.16
Automated Data Collection	6.6%	11.0%	9.8%	51.1%	21.5%	3.70	1.12
Herd Inventory Management	6.9%	13.9%	9.5%	52.1%	17.7%	3.60	1.14
Disease and Health Monitoring	9.1%	16.1%	6.0%	49.8%	18.9%	3.53	1.23
Grazing Management	8.2%	12.9%	8.5%	49.2%	21.1%	3.62	1.19
Record keeping and Traceability	10.4%	14.8%	6.9%	48.9%	18.9%	3.51	1.25
Market Opportunities	7.3%	18.6%	6.3%	50.8%	17.0%	3.52	1.18
						3.58	1.15

Where SD is Strongly Disagree, D is Disagree, N is Neutral, A is Agree, SA is Strongly Agree, and STD is the standard deviation.

4.7 A RFID framework for the management of livestock in Nyeri County Kenya

Framework-specific guidelines for using RFID in implementation for managing livestock in Nyeri County, Kenya, by Small-scale farmers.

The general workflow of the guidelines is as follows :

- Planning and Preparation
- Infrastructure Setup
- Tagging and Data Management
- Training
- Data Integration and Analysis
- Maintenance and Support

The proposed RFID framework is beneficial to the small-scale farmers in Nyeri because it will ensure

- Automation: RFID eliminates the need for manual scanning, enabling faster and more accurate data capture.
- Efficiency: The ability to track and identify multiple animals simultaneously improves inventory management, reduces errors, and enhances supply chain visibility.
- Real-time Tracking: RFID enables real-time monitoring of animals, enhancing security and enabling timely decision-making example, when an animal is classified red, the farmers can be isolated, and the veterinary can make further diagnoses.
- Scalability: RFID frameworks can be scaled to accommodate large-scale livestock farming and support diverse applications.

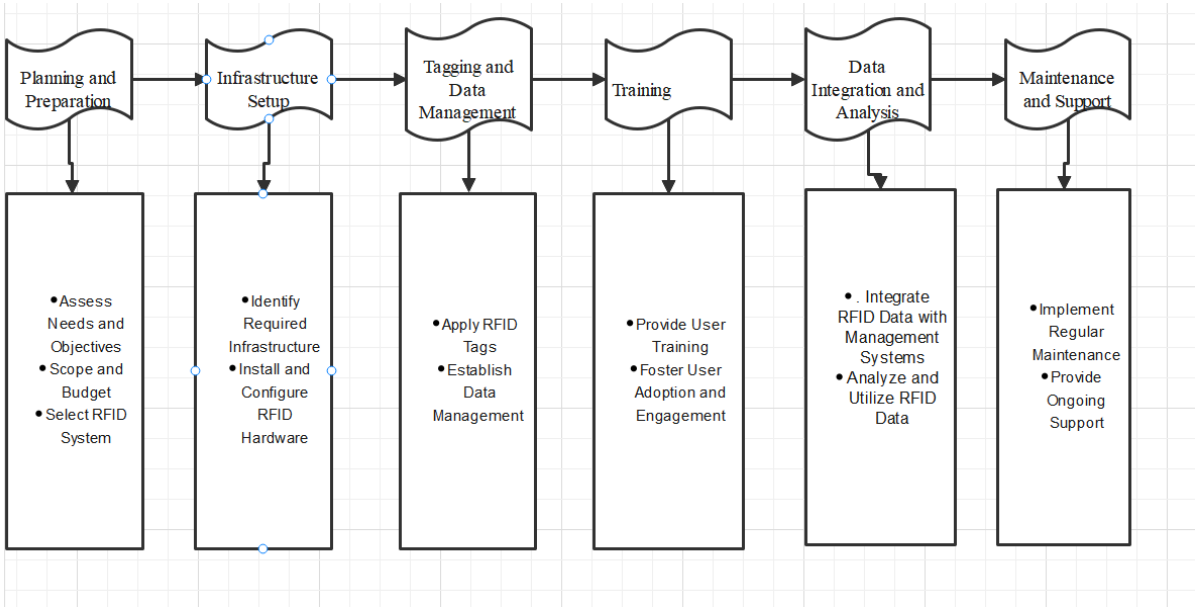


Figure 4.12: A framework-specific guideline for the use of RFID in implementation for the management of livestock in Nyeri County, Kenya, by Small-scale Farmers

Source: Researcher 2023

1. *Planning and Preparation: a. Assess Needs and Objectives:*

The goals that RFID technology can address in livestock management are;

Inventory Management: RFID tags can help maintain accurate and up-to-date livestock inventory records. Farmers can quickly count and track animals by scanning the tags, ensuring the numbers match their records. This is particularly useful during large-scale operations or when managing multiple herds. Disease Control and Monitoring: RFID technology can aid in disease control by enabling the rapid identification and tracking of infected animals. By having a centralized database that records the movements and interactions of each animal, it becomes easier to identify potential disease spread patterns and take necessary preventive measures. Traceability and Food Safety: RFID tags can be used to track the entire lifecycle of an animal, from birth to processing. This allows for improved traceability, ensuring that the origin of the meat or dairy products can be easily identified. In the event of a food safety issue or a product recall, RFID technology helps to locate and remove affected animals from the supply chain more efficiently. Data Collection and Analysis: RFID tags can be combined with sensors to collect various data points, such as animal behaviour, feeding patterns, and health indicators. This data can be analyzed to gain insights into the overall health and well-being of the animals, enabling better decision-making in breeding, feeding, and overall herd management. Efficient Handling and Sorting: RFID technology can be integrated into handling systems, such as gates or chutes, to automatically sort and direct animals based on predetermined criteria. This reduces the need for manual intervention, speeds up processes, and minimizes stress on both animals and handlers. Grazing Management: RFID tags can monitor and manage grazing patterns. By tracking the movements of animals, farmers can ensure optimal utilization of pasture resources, prevent overgrazing in specific areas, and implement rotational grazing strategies for better land management.

Determine the desired outcomes, such as improved traceability, enhanced operational efficiency, and better animal health management.

Improved Traceability: RFID enables accurate and reliable tracking of individual animals throughout their lifecycle. The desired outcome is a comprehensive and easily accessible record of an animal's movements, locations, and interactions. This improves traceability, allowing for better quality control, compliance with regulations, and faster response in case of disease outbreaks or product recalls. Enhanced Operational Efficiency: RFID technology streamlines various processes in livestock management, leading to improved operational efficiency. The desired outcome is to automate tasks such as animal identification, inventory management, sorting, and data collection. This reduces manual labour, minimizes errors, and increases productivity, optimizing resource utilization and saving time and costs. Better Animal Health Management: RFID can contribute to improved animal health management. The desired outcome is to use RFID tags with integrated sensors to monitor vital signs, behaviour, feeding patterns, and other health indicators. Real-time data collection helps detect deviations, identify potential health issues early on, and enable timely intervention. This proactive approach improves animal health, reduces disease incidence, and improves welfare. Enhanced Breeding and Genetic Management: RFID technology can assist in tracking and managing breeding programs. The desired outcome is to use RFID tags to record and analyze breeding data, such as mating dates, genetic traits, and parentage information. This enables more informed breeding decisions, facilitates genetic improvement programs, and helps optimize breeding stock selection for desired traits. Improved Data-Driven Decision-Making: RFID and data analysis enable data-driven decision-making. The desired outcome is to collect and analyze data from RFID tags, sensors, and other sources to gain insights into animal behaviour, performance, and environmental factors. This information can inform decisions related to nutrition, health treatments, reproduction, and overall herd management,

leading to optimized practices and better outcomes. Increased Compliance and Transparency: RFID technology promotes regulatory compliance and enhances transparency in livestock management. The desired outcome is to have accurate and accessible records of animal movements, treatments, and inputs, ensuring compliance with animal welfare standards, traceability requirements, and food safety regulations. This fosters consumer trust and confidence in the livestock industry. Risk Mitigation and Disease Control: RFID aids in risk mitigation and disease control strategies. The desired outcome is to utilize RFID technology to monitor and control animal movements, quickly trace contacts in case of disease outbreaks, and implement targeted containment measures. This helps reduce the spread of diseases, minimize economic losses, and safeguard animal and public health.

Determine Scope and Budget:

The scope of the RFID implementation project will be done in three phases, and the first phase will focus on beef cattle; the number of animals to be tagged will be 50 per sub-county, RFID will be utilized will be in every sub-county, and the timeline and the project will last six months.

Allocate a budget for RFID equipment, tags, software, and any required infrastructure.

RFID Equipment	Passive tags	Android handheld readers	Internet Router	Cloud solution
Price in USD	5	600	39	50
Total in USD	694			

Select RFID System:

The Core Components of an RFID Framework are;

- RFID Tags: Small electronic devices containing a unique identifier can be attached to objects or embedded in products for the farmers in Nyeri County; they will use RFID Implantable Microchips because it is a cheaper and reusable low frequency (L.F.) band commonly used for livestock identification systems (125-134 kHz).
- RFID android Readers are handheld devices or mobile terminals that run on the Android operating system. These readers have built-in RFID capabilities, such as RFID antennas and the ability to read and write data to RFID tags. The reader is also best because it is cheap and affordable to small-scale farmers in Nyeri County. It is also handheld, so it will be easy for the farmers to handle.
- RFID Middleware: Software that acts as a bridge between the RFID hardware and backend systems, managing data collection, filtering, and processing.
- Backend Systems: Databases that store and manage the collected RFID data, providing functionalities for data analysis, reporting, and integration with other systems.

2. ***Infrastructure Setup:*** Install and Configure RFID Hardware:

- Strategically position RFID readers and antennas in areas where animals are handled, ensuring optimal tag detection and read range.
- Follow manufacturer guidelines for installation, including proper grounding, cabling, and power supply.

3. Tagging and Data Management: a. Select and Apply RFID Tags:

- Configure tags

Table 4.9: Configuration of the Tag number

First three numbers=country code	The fourth number is = the county code	The sixth letter=contituencies	The eighth number=Animal serial number	The last letter=Animal type

Train personnel on proper tag application techniques, ensuring accurate and secure attachment to the animal.

Establishing Data Management:

- Develop standard operating procedures (SOPs) for data collection, recording, and storage.

Tag Number	Animal type	Age	Location	Temperature	Weight	Analysis Results	Outcomes	Action
25420K001F	Friesian	2	Kieni	37	254kgs	=IF(AND(Age_of_Cow-3.5<>"",Weight<346.1,AND(Temperature>=36.7,Temperature<=39.1)),"yellow","")		Improve on the diet

25420A001M	Ayrshire	3	Mathira	36.7c	346.1kgs	=IF(AND(Age=3.5, Weight=346.1, Temperature>=36.7, Temperature<=39.1), "green", "")		Ready for Market
25420G001G	Guernsey	2.5	Mukurweini	39 c	300 kgs	=IF(AND(Age_of_Cow-3.5<>"",Weight<346.1,AND(Temperature>=36.7, Temperature<=39.1)),"yellow","")		Improve on the diet
25420J001J	Jersey	3	Nyeri	104 c	200kgs	=IF(AND(Age_of_Cow-3.5<0, Weight_of_Cow-346.1<0, Temperature>100), "red", "")		Animals are to be isolated and called the veterinarian.
25420E0010	East African Zebu		Othaya	110	290kgs	=IF(AND(Age_of_Cow-3.5<0, Weight_of_Cow-346.1<0, Temperature		Animals are to be isolated and called the veterinarian.

						>100), "red", "")		
25420S001S	Sahiwal		Tetu	39	346	=IF(AND(Age=3.5, Weight=346.1, Temperature>=36.7, Temperature<=39.1), "green", "")		Ready for Market

Data Management: The RFID framework addresses data management limitations.

a. Data Capture and Accuracy:

- Real-time Data Capture: the framework enables real-time data capture, ensuring timely and accurate information about tagged items. The handheld Android reader is a high-speed reader.
- Data Validation and Error Handling: the framework incorporates data validation mechanisms to ensure the accuracy and integrity of captured data. It involves implementing error-checking algorithms, data redundancy checks, or automatic correction techniques.

b. Data Storage and Scalability:

- Scalable Data Storage: the framework accommodates large volumes of RFID data; the data storage will use cloud-based solutions, allowing seamless expansion as data volumes increase.

- Data Compression and Aggregation: The framework utilizes data compression techniques or data aggregation methods to optimize storage capacity while retaining important information, which helps to reduce storage costs and improve overall system performance.

c. Data Integration and Interoperability:

- Integration with Analytics and Reporting Tools: the framework enables integration with analytics and reporting tools to derive meaningful insights from RFID data. The framework encompasses robust data visualization tools, sophisticated analytics algorithms, and highly customizable reporting dashboards.

d. Data Security and Privacy:

- Encryption and Access Control: the framework incorporates encryption techniques and access control mechanisms to protect RFID data from unauthorized access or tampering. Explain the use of secure communication protocols and user authentication measures.
- Audit Trails and Compliance: the framework maintains audit trails to track data access, modifications, or deletions. The framework complies with data protection regulations and can generate audit reports for regulatory purposes.

e. Data Analytics and Insights:

- Real-time Reporting and Alerts: the framework enables real-time reporting and alerting mechanisms to identify and promptly address data anomalies or critical events. Enables prompt decision-making and proactive management actions

- Data Visualization: Emphasize using interactive data visualization tools like Power BI within the framework. Users can effortlessly interpret and explore RFID data using intuitive visual representations such as charts, graphs, or heat maps.

4. Training: a. Provide User Training:

• Conduct comprehensive training sessions for farmers, farm staff, and livestock handlers on RFID technology and its applications.

• Train users on tag application techniques, equipment operation, data collection procedures, and troubleshooting.

Foster User Adoption and Engagement:

• Encourage users to actively participate in the RFID implementation process and provide feedback on challenges and successes.

• Promote a continuous learning and improvement culture by organizing workshops, seminars, or discussion forums related to RFID technology.

5. Data Integration and Analysis: a. Integrate RFID Data with Management Systems:

• Ensure seamless data flow and synchronization across different platforms to maintain data consistency.

a. Real-time Reporting and Alerts: the framework enables real-time reporting and alerting mechanisms to identify and promptly address data anomalies or critical events. Enables prompt decision-making and proactive management actions

b. Data Visualization: Emphasize using interactive data visualization tools like Power BI within the framework. Users can effortlessly interpret and explore RFID data using intuitive visual representations such as charts, graphs, or heat maps.

Analyze and Utilize RFID Data:

• Develop data analysis and utilization procedures to derive insights and support decision-making using the categorization classification.

Table 4.10: Categorization of Outcome

Green	The animal is classified Green when the Temp=(36.7-39.1), weight = 346.1kgs, water intake is 22 litres per day, and food intake is 12kgs-15kg.
Yellow	The animal is classified Yellow when the Temp=(36.7-39.1), weight = is between 200-300, water intake is less22 liters per day, and food intake is less12kgs-15kg
Red	The animal is classified as Red when the Temp=(over 50) is not taking food and water.

• Train users on interpreting RFID data, identifying trends, and leveraging the information for improved livestock management practices.

6. Maintenance and Support: a. Implement Regular Maintenance:

- Schedule monthly maintenance routines for RFID equipment, including cleaning antennas, checking connections, and replacing tag batteries to ensure everything works properly.
- Develop a record of maintenance activities to track equipment performance and ensure uninterrupted operation.

Provide Ongoing Support:

- Establish a support system to address user queries, troubleshoot issues, and provide technical assistance.
- Offer timely firmware/software updates and inform users about any relevant advancements or improvements in RFID technology.

Figure 4.13 The RFID framework for managing livestock in Nyeri County, Kenya, by Small-scale farmers.

- In the RFID framework for livestock management in Nyeri County, nine components work together to achieve this. The nine components include the RFID antenna and RFID handheld reader, base station, farm computer that connects to the web, GPS reader, Web server, livestock farmer with GPS start intelligent devices, the remote control center for grazing route monitoring, and livestock animals.
- The livestock farmer/herder tags the livestock animals with RFID tags. The RFID tags are of different frequencies, and the livestock farmer has to select the best ones. The livestock farmer starts the smart device.
- The GPS receives the signals from the farmer's handled device. The GPS device sends the signals to the farm computer or mobile phone connected to the web server or web app via the internet.

- In the grazing field, the RFID tags with the animals send signals received by the RFID antenna and handheld reader. The signals with information about the livestock's location and type are sent to the base station and further sent to the farm computer. The RFID signals containing animal information like location, type of livestock, and animal health condition are sent to the livestock farmer through the handheld device.

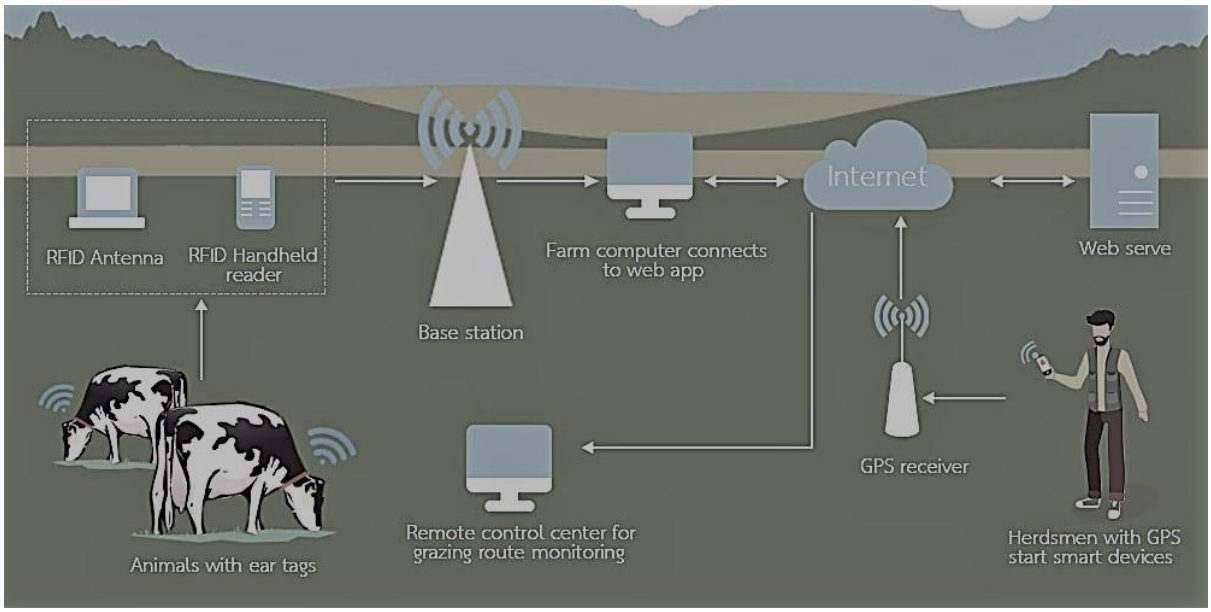


Figure 4.13: A framework-specific guideline for the use of RFID in implementation for the management of livestock in Nyeri County, Kenya, by Small-scale farmers

Source: Researcher 2023

CHAPTER FIVE

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This chapter summarises the study's findings, presents conclusions, and makes recommendations and suggestions for further research based on the study's findings.

5.2 Discussions

The study's first objective was to identify the factors that influence the adoption of a radio frequency identification framework for livestock management among small-scale farmers in Nyeri County. Various factors were assessed, including technology-related, cost implications, environment and facility factors, and data management factors. Methods to achieve this goal include maintaining a database of information about each animal, including its name, location, medical history, diet, and treatment history, and removing the records of animals that have since died or been relocated from the database. The automated milking system reduces the cows' stress and hostility. The results of a previous investigation support these findings. (Bell, Harley & Bryman, 2022). RFID provides an extra layer of security to ensure that only the intended animal receives a specific prescription.

A negative and statistically significant relationship was found between the coefficient of cost implications factors and the adoption of the RFID framework for livestock management among small-scale farmers. The installation of farm animal RFID systems could be too expensive. Small-scale livestock farmers fail to use RFID because of the costs associated with RFID livestock identification. Each head of livestock would have to be registered and remunerated for the annual registration fee for small-scale producers. Though accurate, large-scale livestock growers and organizations can use this technology to compile official records,

choose appropriate base stocks for small-scale farmers, and breed these animals accordingly. Because of the higher costs associated with RFID acquisition and maintenance, small-scale livestock farmers may find it challenging to maintain the use of RFID in the identification of their livestock. The results are in tandem with Hammer, et al. (2017), who conducted a cost-benefit analysis of a UHF-RFID system for animal identification, simultaneous detection, and hotspot monitoring of fattening pigs and dairy cows. The costs associated with the UHF-RFID system include material costs (hard and software as well as initial fitting with UHF ear tags for dairy cows), fitting and installation costs, costs occurring on an annual basis for new UHF transponder ear tags, energy costs, and costs for depreciation and interest. On the same note, a study by Chudy-Laskowska (2018 on factors influencing the decision to implement an RFID system using questionnaire-based surveys established that the cost of system implementation is seen as the most significant factor in an RFID system. Likewise, Zhang, et al. (2017) established that cost issue is an important limiting factor in implementing RFID technology and includes the cost and use of tags and readers and other hardware devices, management system software upgrades, and follow-up system maintenance costs. Shear, et al. (2019) identified the cost of RFID tags, installation, and operations as significant costs associated with using RFID.

It was further established that the environment and facility factors had a positive and statistically significant relationship with implementing the RFID framework for livestock management among small-scale farmers (β=.343, p-value=.000<0.05). Environmental issues have been found to interfere with the installation and operations of RFID technologies. In some cases, where RFID tags are used in the identification and traceability of livestock, environmental challenges interfere with the normal operations of RFID tags. H.F. and UHF frequencies are the most commonly used for RFID technology applications since they are the most widely available. Furthermore, environmental factors like water and canopy

substantially impact these two frequencies. When liquids are present, RFID signals are absorbed, reducing or even stopping transmission between tags and readers, while plant canopy may interfere with the transmission of RFID signals. Metal is another environmental aspect to consider. Metal can deflect RFID; however, the solution is to create a channel for the radio waves to flow through the substance. The results align with Ruiz-Garcia and Lunadei (2011), who established that operation in harsh environments, dirt, extreme temperatures, and reduction of signal strength due to propagation in crop canopy influenced the successful adoption of RFID technologies. Similarly, Mosadegh and Sedghy (2018) established that RFID tags' readability is sensitive to environmental factors such as extreme temperatures, dust, moisture, metallic objects, and the high-water content of tagged materials.

Likewise, the coefficient of data management factors had a positive and statistically significant relationship with implementing the RFID framework for livestock management among small-scale farmers (β=.240, p-value=.000<0.05). The results imply that a one-unit improvement in data management factors results in .240 units increase in the adoption of RFID framework for livestock management among small-scale farmers in Nyeri County. RFID technology installation necessitates a thorough understanding of data management. Reliable data management is necessary to ensure that the large amounts of information generated by RFID systems can be processed effectively.

Large amounts of RFID data and data integration across numerous facilities will provide farmers with hurdles in RFID data management. As previously indicated, various livestock tags can generate vast data using RFID systems, resulting in information overload. For this topic, the technology demands robust IT systems capable of handling the issue's complexity. The results concur with Jung and Lee (2015), who found that the diffusion and applications of RFID can involve unexpected disadvantages, including technological deficiency, uncomfortable privacy issues, and unequal distribution of digital power and literacy.

Likewise, Hossain, et al. (2017), studying the development and validation of a two-staged adoption model of RFID technology in livestock businesses, found that technological interoperability and data inconsistency significantly influence the acceptance of RFID technology in livestock businesses.

Small-scale farmers' adoption of RFID technology for livestock management was positively and significantly influenced by technological factors (=.414, p-value=.0000.05), with a one-unit change in technological factors resulting in a.414-unit increase in RFID framework adoption. In terms of technology itches, mechanical damage, environmental damage, tag collision, and print quality degradation due to electromagnetic fields and nearby electrical equipment (Khalid et al., 202) affect the adoption of RFID technology in livestock management. In addition, the failure of tags characterises the RFID technologies in livestock management. The results concur with a study by OECD (2018) on OECD Policy Guidance of RFID technologies that identified technical challenges imposed by physics laws, such as interference, power management, reflection, and signal attenuation. Similarly, Hossain and Quaddus (2012) established that the technology influences RFID adoption, whereas the continuance of RFID technology depends on confirmation and satisfaction from using the technology.

The second objective was to develop a radio frequency identification framework for livestock management in Nyeri County, Kenya. The development of the RFID model for livestock management in Nyeri County, Kenya, is based on factors that influence the adoption of RFID for livestock management. The critical benefits observed in livestock management in Nyeri County using RFID technologies include pasture control, disease outbreak, and water point management. According to (Voulodimos, et al., 2010), the RFID model framework development for livestock management must consider the benefits and costs associated with it. The process requires acquiring the necessary software and hardware materials and expert

knowledge. In the RFID model framework for managing livestock by small-scale farmers, the RFID readers collect cattle information in the grazing. Likewise, livestock information is directly keyed to the keyboard. The information is sent to the data storage device and the data storage device. The data storage device contains specific information for each of the cattle. The information is further transmitted to the daily cattle information management system, where a decision is made regarding pasture control, disease outbreak detection, water point management, animal identification/traceability, animal feeding control, and medicine administration for the cattle.

The study's third objective was to evaluate the Radio Frequency Identification technology's benefits in managing livestock among small-scale farmers in Nyeri County. It is perceived that RFID technologies have brought certain benefits to the management of livestock. The majority of the livestock farmers agreed that the use of RFID technology had brought significant benefits. The benefits enabled them to improve livestock production and reduce the cost, enhance the livestock's security and traceability, generate timely, accurate, and granular data helpful in livestock management, and enhance the livestock feeding schedule and rationing monitoring. Other benefits included improved automated livestock monitoring resulting in few labourers, enhanced ability to correctly trace and identify the livestock in the field and adequately manage the cattle feeding programme. The aggregate mean of 3.53 implied that most livestock farmers agreed that RFID technologies had brought certain benefits in livestock management.

RFID has been used in the livestock sector to track the location and identify farm animals. An RFID tag is tied to the animal, or an RFID chip is implanted. After installing the RFID tag or implanting the RFID chip, the animal can be located, identified, and recognised anywhere within the locality serviced by the RFID technology. The RFID technology has been exalted

in identifying and tracking livestock inventory, recording essential health data for each animal, managing animal diseases, and combating livestock theft. RFID can be used to track livestock from birth through slaughter. Tools to appropriately value animals, assess farm costs, and correlate data for effective management and reducing losses due to disease outbreaks or thefts will be provided for farmers. The results concur with Barge, et al. (2013), who studied RFID technologies for livestock management and meat supply chain traceability in New Zealand and found that RFID technologies have been helpful in animal identification and tracking.

Similarly, Dogan, et al. (2016), in a study on radio frequency identification systems in animal monitoring, established that RFID technologies have proved effective in monitoring, tracking, and identifying livestock, preventing theft and fraud. Ibrahim, et al. (2016), studying the use of RFID in curtailing cattle rustling in Katsina State, Nigeria, also indicated that RFID uses in identifying livestock has been beneficial in combatting cattle theft. Gwaza and Gambo (2017) noted that read identification data from the RFID tag in livestock management facilitated the monitoring of cattle breeding activity, animal identification, sires, and dams of progenies for accurate record keeping. Also, Zhang, et al. (2017), investigating the application of RFID in the agricultural product industry, established that RFID has been essential in livestock traceability and cold chain monitoring.

All the animal identification methods available to farmers in Nyeri County were found to be ineffective by those who participated in the study since none of them had worked. According to the participants, RFID chips could validate animal identification by scanning the animal and displaying the results on a computer. The outcomes align with those of (Bell, Harley & Bryman, 2022). Using RFID technology to keep tabs on and identify cattle is a good idea. In addition to improving farm data administration and security, participants have recognized

RFID for making it feasible to update batch information, track parturition, and vaccinate livestock of the same breed. Methods to achieve this goal include maintaining a database of information about each animal, including its name, location, medical history, diet, and treatment history, and removing the records of animals that have since died or been relocated from the database. The automated milking system reduces the cows' stress and, consequently, their hostility. The results of a previous investigation support these findings. (Bell, Harley & Bryman, 2022). In order to ensure that only the intended animal receives a particular prescription, RFID provides an extra layer of security.

5.3 Summary of Main Findings

The study's first objective was to identify the factors that influence the adoption of a radio frequency identification technology for livestock management among small-scale farmers in Nyeri County. Various factors were assessed, including technology-related, cost implications, environment and facility factors, and data management factors. It was found that technology-related factors, cost implications, environment and facility factors, and data management factors influence the adoption of the RFID framework for livestock management among small-scale farmers in Nyeri County.

A negative and statistically significant relationship was found between the coefficient of cost implications factors and the adoption of the RFID framework for livestock management among small-scale farmers. It was further established that the coefficient of environment and facility factors had a positive and statistically significant relationship with implementing the RFID framework for livestock management among small-scale farmers. Likewise, the coefficient of data management factors had a positive and statistically significant relationship with implementing the RFID framework for livestock management among small-scale

farmers. The technology factors positively and significantly influenced the adoption of the RFID framework for livestock management among small-scale farmers.

Objective two sought to develop a radio frequency identification framework for livestock management in Nyeri County, Kenya. The development of the RFID model for livestock management in Nyeri County, Kenya, is based on the benefits of RFID in livestock management and factors that influence the adoption of RFID for livestock management. The process requires acquiring the necessary software and hardware materials and expert knowledge. In the RFID model framework for managing livestock by small-scale farmers, the RFID readers collect cattle information in the grazing. Likewise, livestock information is directly keyed to the keyboard. The information is sent to the data storage device and the data storage device. The data storage device contains specific information for each of the cattle. The information is further transmitted to the daily cattle information management system, where a decision is made regarding pasture control, disease outbreak detection, water point management, animal identification/traceability, animal feeding control, and medicine administration for the cattle.

The study's third objective was to evaluate the Radio Frequency Identification technology's benefits in livestock management among small-scale farmers in Nyeri County. It is perceived that RFID technologies have brought certain benefits to the management of livestock. The majority of the livestock farmers agreed that the use of RFID technology had brought significant benefits. The benefits enabled them to improve livestock production and reduce the cost, enhance the livestock's security and traceability, generate timely, accurate, and granular data helpful in livestock management, and enhance the livestock feeding schedule and rationing monitoring. Other benefits included improved automated livestock monitoring resulting in few labourers, enhanced ability to correctly trace and identify the livestock in the field and adequately manage the cattle feeding programme. The aggregate mean of 3.53

implied that most livestock farmers agreed that RFID technologies had brought certain benefits in livestock management.

5.4 Conclusions

The conclusions of the study are based on the study findings. The study also concludes that technology factors had the most significant favourable influence on implementing RFID for livestock management in Nyeri County, followed by environment and facility factors. Data management had the most negligible positive influence on implementing RFID for livestock management in Nyeri Count. It was also established that cost implication factors negatively influenced the adoption of RFID for livestock management in Nyeri County. Nyeri County farmers appear to struggle with the initial cost of employing RFID technology to reproduce and manage indigenous livestock breeds. The management of RFID data is complicated by the sheer volume of data and the need to integrate data from numerous locations. On the other hand, the Nyeri farmers lacked the most basic RFID skills, such as record-keeping and information technology (ICT).

The study indicated that small-scale livestock farmers in the Nyeri region needed an RFID system tailored to their needs. It is critical to have a comprehensive livestock management system that keeps track of animal data, including their diet, health, and behaviour. Local farmers in Nyeri County should store animal identity data for a wide range of species with the help of various RFID tags (button/ear tags, boluses, injectable glass tags).

It was also concluded that the development of RFID for livestock management should base on the benefits and challenges of RFID in livestock management and factors that influence the adoption of RFID for livestock management. The benefits include improved livestock production and reduced cost, enhanced security and traceability of the livestock, generation of timely, accurate, and granular data helpful in the management of the livestock, enhanced

monitoring of the livestock feeding schedule and rationing, enhanced ability to trace and identify the livestock in the field correctly and adequately management of cattle feeding programme. However, using RFID also comes with costs, privacy, and animal health issues.

According to the study findings, RFID-based livestock identification and management systems are incredibly effective. An RFID-based system for monitoring feeding and rationing will allow farmers to increase cattle productivity while decreasing production costs. It was concluded that several benefits are associated with RFID in managing livestock cattle. The benefits include improved livestock production and reduced cost, enhanced security and traceability of the livestock, generation of timely, accurate, and granular data helpful in livestock management, and enhanced monitoring of the livestock feeding schedule and rationing. Other benefits included improved automated livestock monitoring resulting in few labourers, enhanced ability to correctly trace and identify the livestock in the field and adequately manage the cattle feeding programme. However, using RFID also comes with costs, privacy, and animal health issues.

5.5 Implications of these findings for the livestock industry

The study recommends the following:

Given that technology may be complicated for some, Nyeri County, through the county government, should collaborate with institutions that provide training to farmers to offer free training on the benefits and use of RFID technology for farmers. Practical training will solve problems arising from environmental issues, lack of knowledge, and experience, giving farmers the confidence to adopt the technology. Framers will quickly adapt to the technology and reap benefits such as efficient production, less labour, and reduced cost of production.

Kenya Agriculture and livestock research organization's (KALRO) primary mandates are to develop disease control technologies and an effective traceability system; RFID is one

technology that can solve disease control through identification and tracking. Therefore, the Organisation should ensure they take primary responsibility for managing the data. Data Management is a big challenge to farmers; consequently, the organization should consider the principal responsibility of Data Management because they have the human resources to help the organization meet its mandate and relieve the Baden from the farmer.

There are several benefits associated with the use of RFID in livestock management. The Nyeri County, through the Ministry of Livestock, the Ministry of Communication, and the national government through the Ministry of Agriculture, may conduct sensitization and awareness programs on the benefits of RFID in livestock management. Livestock companies may learn how to implement RFID and the importance of consistent use to protect client data in these courses.

5.6 Suggestion for Further Research

The study only focused on the benefits associated with RFID in livestock management. It also focused on factors that affect the adoption of RFID. However, the study did not narrow down to specific data management breaches in using RFID. Future studies may seek to elaborate on the data management and breach issues in the use of RFID in the management of livestock. Regulatory framework impacts the use of RFID in livestock management. Future studies may investigate the regulatory laws, policies, and guidelines for deploying RFID in livestock management.

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APPENDICES

Appendix 1- Questionnaire

ASSESSING THE ADOPTION AND IMPACT OF RADIO FREQUENCY IDENTIFICATION TECHNOLOGY FOR LIVESTOCK MANAGEMENT AMONG SMALL-SCALE FARMERS IN NYERI COUNTY, KENYA

My name is Doreen Njoroge, a student at African Nazarene University School of Computer Studies researching the adoption of radio frequency identification and its impact on livestock management in Nyeri County. Please take a few minutes of your time to complete this questionnaire. Your involvement in this research will be appreciated, and you are requested to answer the questions honestly. The responses will be confidential, not be linked with any account, and will be used only for this study.

Please answer all the questions by filling in the blank spaces or ticking an option where applicable.

Section A: Demographics

1. Kindly indicate your gender

   Male [ ] Female [ ]

2. What is your age bracket?

Below 30 years [ ] 31-40 years [ ] 41-50 years [ ] Above 50 years [ ]

3. Education background? Tick ☑ where appropriate.

   a. Primary Level [ ]

   b. Secondary Level [ ]

c. Polytechnic Level [ ]

d. University Level [ ]

4. How long have you practised livestock farming? Tick ☑ where appropriate.

a. Less than five years [ ]

b. 6-10 years [ ]

c. 11-15 years [ ]

d. Above 16 years [ ]

5. Indicate the number of heads of cattle you rear.

a. Less than five cattle [ ]

b. 6-10 cattle [ ]

c. 11-20 cattle [ ]

d. 21-30 cattle [ ]

e. Over 31 cattle [ ]

6. Size of land for livestock farming?

f. 1/8 acre [ ]

g. ¼ acre [ ]

h. ½ acre [ ]

i. 1-2 acres [ ]

j. 3-5 acres [ ]

k. Over 5 acres [ ]

7. Do you think that the current method of livestock farming is effective?

   Yes [ ] No [ ]

8. What are the challenges that you currently face in Livestock farming?

……

……

……

9. What digital technology and other devices do you use on the farm? (Please tick all that apply) Smartphone (iPhone) [ ] Smartphone (android) [ ] Computer[ ] Tablet [ ] EID reader [ ] None [ ]

10. For how long have you been using RFID in the management of livestock?

    e. Less than two years [ ]

    f. 3-6 years [ ]

    g. 7-10 years [ ]

    h. 11 years and above [ ]

11. How helpful has RFID been in the management of livestock?

    i. Not helpful at all [ ]

    j. Fairly helpful [ ]

    k. Helpful [ ]

    l. Very helpful [ ]

Section B: Factors Influencing the Adoption of Radio Frequency Identification Technology for livestock management among small-scale farmers.

To what extent do you concur with the following statements on the factors that affect adopting Radio Frequency Identification technology in livestock farm management? Use a scale of 1 to 5. Where 1 = strongly disagree, 2 = Disagree, 3 = Neutral, 4 = agree and 5 = strongly agree.

Statements on the factors that affect the adoption of radio frequency identification (RFID) technology	**1**	**2**	**3**	**4**	**5**
Technology challenges The acquisition of appropriate RFID technologies is a problem for me.					
The deployment and use of RFID technologies in the management of my livestock.					
Maintaining RFID equipment is a significant problem because I am not conversant with it.					
Mechanical damage of RFID as a result of electromagnetic fields and nearby electrical equipment					
Tag collision and failure of tags undermining the effectiveness of RFID technologies in livestock management					
Cost Implications The cost of purchasing RFID tools is exorbitantly high.					
I find the cost of implementing RFID to be way my abilities.					

The cost of maintaining and replacing RFID tools in case of damage or they are lost in the grazing field.					
The cost of complying with privacy guidelines associated with the use of RFID technologies					
The cost of managing health issues associated with the use of RFID technologies in the management of cattle					
Environment and facility factors Plant canopy is a problem in the deployment of RFID in livestock management.					
Moisture content and precipitation often damage livestock traceability tags.					
The variability of temperature ranges impacts the proper operations of the RFID tags in livestock.					
Moisture interferes with the transmission of RFID signals between tags and readers.					
The deflection of RFID signals by natural metallic material beneath the earth and surrounding					
Data management Related data privacy issues in the use of RFID					
The storage of RFID data					
Regulations guiding the use of RFID data					

Large amounts of RFID data and integration across numerous facilities give farmers hurdles in RFID data management.					
Data Management that affects the implementation of RFID technology in livestock farming					

Section C: Benefits of Implementing Radio Frequency Identification Technology in the Management of Livestock.

Evidence shows that RFID helps livestock farmers in many ways, including identification, traceability, automatic scanning and weighing, electronic feed monitoring, and electronic monitoring. This technology optimizes existing practices, improves reliability, and increases livestock farming productivity. To what level do you agree with the following statements on the benefit of Radio Frequency Identification technology in livestock management in Nyeri County? Use a scale of 1 to 5. Where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree and 5 = Strongly Agree.

Statements on the benefits of implementing radio frequency identification (RFID) technology	**1**	**2**	**3**	**4**	**5**
With the use of RFID technology, I have been able to improve livestock production and reduce the cost.					
With the use of RFID technology, I have been able to enhance the security and traceability of the livestock.					
The RFID technology has enabled the generation of timely, accurate, and granular data on the livestock on the farm.					

The RFID technology has enabled me to enhance the monitoring of the livestock feeding schedule and rationing.					
There has been improved monitoring of the livestock management of automation hence leading to few labourers.					
With the use of RFID, I have been able to trace and identify the livestock in the field.					
The RFID has allowed me to manage the feeding programme of my livestock properly.					

Section D: Implementation of radio frequency identification framework for livestock management among small-scale farmers.

Indicate the level at which RFID has enabled you to manage the livestock on your farm. Use a scale of 1 to 5. Where 1 = strongly disagree, 2 = Disagree, 3 = Neutral, 4 = agree and 5 = strongly agree.

Implementation of RFID for Livestock management in Nyeri County	**1**	**2**	**3**	**4**	**5**
Animal Identification					
Automated Data Collection					
Herd Inventory Management					
Disease and Health Monitoring					
Grazing Management:					

Recordkeeping and Traceability					
Market Opportunities					

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS

Appendix 2- Interview Questions for Industry Experts/Agricultural Officers from Nyeri County

Introduction: This interview will assess your thoughts and feelings about adopting RFID in Nyeri County. The meeting will not be for more than two hours. May I tape the debate to facilitate its recollection? (If yes, switch on the recorder).

Warm-up

First, I would like you to introduce yourself. Can you tell us your name?

Introductory question

- Take a few minutes to consider your experience as a county worker in Nyeri County.
- What do you think are the challenges a livestock farmer faces today?
- Do you think technology like RFID will assist farmers in their current challenges?
- Does the prospect of being able to track animals through the use of RFID technology excite you as a livestock farmer in Nyeri?
- What factors led you not to adopt RFID technology in your farming?

Conclusion

Thank you for participating in a fruitful conversation.

Your opinions will be an essential resource for research.

Appendix 3- Letters Authorization

AFRICA NAZARENE
UNIVERSITY

May 15, 2019

To Whom It May Concern

Dear Sir/Madam,

RE: PROPOSAL APPROVAL FOR DOREEN W. NJOROGE (17M03EMIT009)

The above named is a Master of Applied IT student at Africa Nazarene University. This is to confirm that her research proposal titled "**The Implementation of Radio Frequency Identification on Livestock Management: Case Study in Nyeri County, Kenya**" has been approved for conduct of research, subject to obtaining other permissions and/or clearances that may be required beforehand.

Any support and/or assistance accorded to her will be highly appreciated.

Please feel free to contact me via email on jobuluma@anu.ac.ke in case of further clarity required.

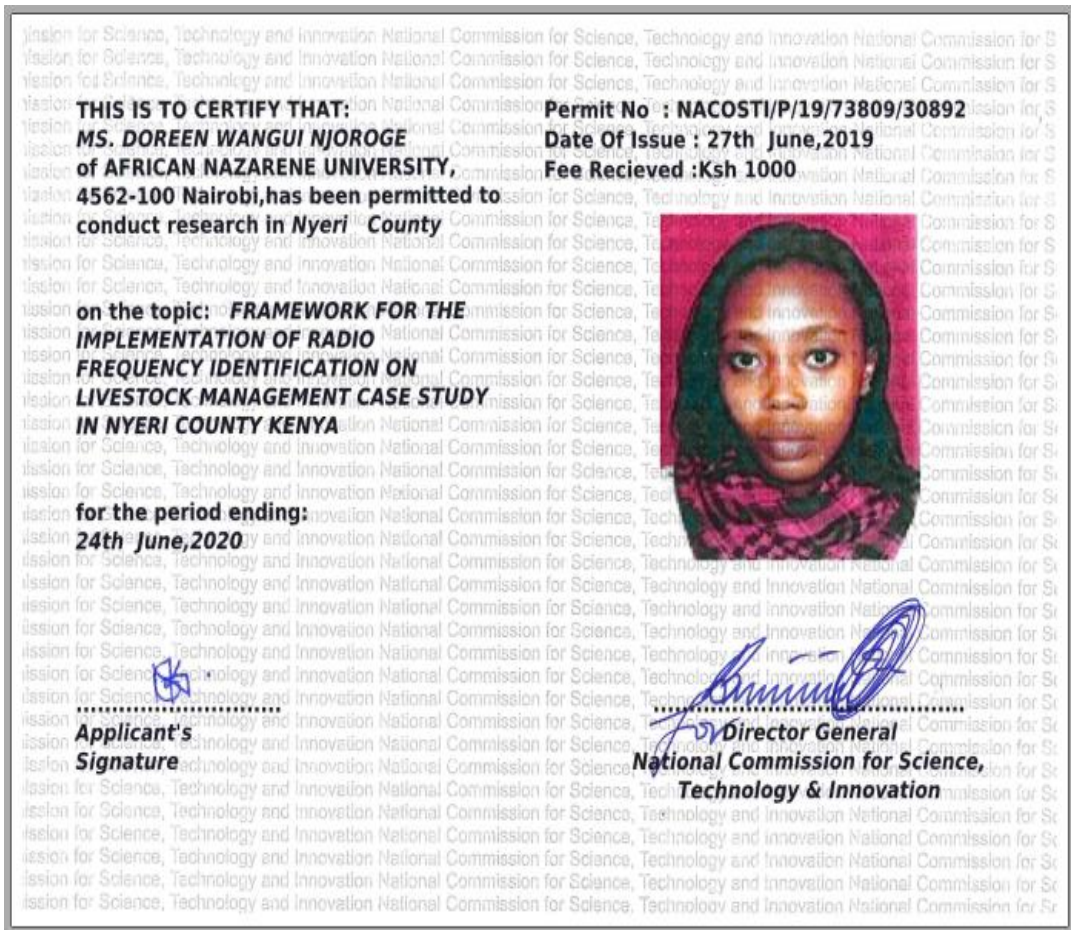
Yours Sincerely,

AFRICA NAZARENE UNIVERSITY
CHAIRMAN
SIGN.....
COMPUTER SCIENCE
P. O. Box 53867, NAIROBI

Obuluma James
Head of Department, Computer and Information Technology

P.O Box 53867 - 00200 Nairobi, Kenya • Tel: 020 252 71701 - 5 • Fax: 020 201 2253 • Cell: 0733 874 111 • Email: registrar@anu.ac.ke • www.anu.ac.ke

Appendix 4- Research Permit



THIS IS TO CERTIFY THAT:
MS. DOREEN WANGUI NJOROGE
of AFRICAN NAZARENE UNIVERSITY,
4562-100 Nairobi,has been permitted to
conduct research in *Nyeri County*
on the topic: *FRAMEWORK FOR THE IMPLEMENTATION OF RADIO FREQUENCY IDENTIFICATION ON LIVESTOCK MANAGEMENT CASE STUDY IN NYERI COUNTY KENYA*
for the period ending:
24th June,2020

Permit No : NACOSTI/P/19/73809/30892
Date Of Issue : 27th June,2019
Fee Recieved :Ksh 1000

.....
Applicant's Signature

.....
Director General
National Commission for Science, Technology & Innovation

Appendix 5-Map of Nyeri County



Appendix 6- Sample Determination Table

N	S	N	S	N		S	N	S	N	S
10	10	100	80	280		162	800	260	2800	338
15	14	110	86	290		165	850	265	3000	341
20	19	120	92	300		169	900	269	3500	246
25	24	130	97	320		175	950	274	4000	351
30	28	140	103	340		181	1000	278	4500	351
35	32	150	108	360		186	1100	285	5000	357
40	36	160	113	380		181	1200	291	6000	361
45	40	180	118	400		196	1300	297	7000	364
50	44	190	123	420		201	1400	302	8000	367
55	48	200	127	440		205	1500	306	9000	368
60	52	210	132	460		210	1600	310	10000	373
65	56	220	136	480		214	1700	313	15000	375
70	59	230	140	500		217	1800	317	20000	377
75	63	240	144	550		225	1900	320	30000	379
80	66	250	148	600		234	2000	322	40000	380
85	70	260	152	650		242	2200	327	50000	381
90	73	270	155	700		248	2400	331	75000	382
95	76	270	159	750		256	2600	335	100000	384

Note: “N” is the population size “S” is the sample size.

Krejcie, Robert V. Morgan, Daryle W., “Determining Sample Size for Research Activities,” Educational and Psychological Measurement, 1970.