A DIGITAL KNOWLEDGE MANAGEMENT SYSTEM FOR BANANA DISEASE CONTROL AT NARO

BY

GROUP 1

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DECLARATION

We hereby declare that this research report is my original work and it has never been submitted to any institution of higher learning for any academic award.

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APPROVAL

This research report on "*A Digital Knowledge Management System for Banana Disease Control At NARO*" has been done under my supervision and is now ready for submission to the East African School of library and Information Science of Makerere University with my Approval.

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DEDICATION

The research report is dedicated to Almighty God who has enabled us come to the end of this three-year course.

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We are grateful and humbly thankful to the Almighty God for enabling us to complete this research successfully. We are also indebted to our families for the moral, emotional and financial support they have provided through our education.

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ABSTRACT

This project focused on the development of a Digital Knowledge Management System for banana disease control at the National Agricultural Research Organisation (NARO), with specific emphasis on cooking banana (matooke) varieties, particularly Kibuzi and Nakitembe. The purpose of the project was to address weaknesses in the current management of banana disease knowledge, including fragmented documentation, delayed retrieval of diagnostic information, limited knowledge sharing, and the risk of losing institutional knowledge. The project was guided by four objectives: to assess how cooking banana-related knowledge, disease diagnostics, and integrated management practices are currently managed at NARO; to identify user, technical, and operational system requirements; to develop the digital knowledge management system; and to test and validate the implemented system.

The project adopted the Waterfall Model, supported by qualitative and descriptive methods. Data were collected from NARO staff and system users through interviews, document analysis, and observation, while system requirements were derived from existing banana disease records, diagnostic protocols, research reports, extension materials, and stakeholder input. The expected outcome is a functional, secure, user-friendly, and centralized digital knowledge management system capable of supporting knowledge capture, storage, retrieval, sharing, reporting, and user authentication. The system is expected to improve timely access to banana disease information, enhance collaboration among researchers and extension officers, preserve institutional memory, and support evidence-based decision-making for improved banana disease control at NARO.

CHAPTER ONE: INTRODUCTION

1.0 Introduction

In the contemporary knowledge-driven economy, organizations increasingly rely on Knowledge Management Systems (KMS) to enhance efficiency, innovation, and decision-making. A Knowledge Management System refers to an integrated set of tools and processes used to capture, store, organize, and disseminate knowledge within an organization to improve performance and support informed actions (Durst & Ferenhof, 2023). These systems facilitate both the management of explicit knowledge such as documents and databases and tacit knowledge embedded in human expertise, enabling institutions to leverage their intellectual assets effectively (Alavi & Leidner, 2021).

The concept of Digital Knowledge Management Systems (KMS) has gained prominence as organizations increasingly recognize knowledge as a critical strategic resource. A Digital Knowledge Management Systems (KMS) as an integrated technological platform facilitates the creation, capture, storage, retrieval, sharing, and application of knowledge in a digital environment to enhance organizational effectiveness and decision-making (Durst & Ferenhof, 2023). These systems combine information technologies such as databases, cloud computing, mobile applications, and analytics tools which transform how knowledge is managed and utilized.

With the rapid advancement of digital technologies, traditional knowledge management approaches that rely on manual processes have increasingly become inadequate. Organizations are transitioning towards digital knowledge management systems, which provide real-time access to information, improved collaboration, and enhance data analytics capabilities (Davenport & Prusak, 1998). In sectors such as Education, Business, Health, Transport and Agriculture, where timely and accurate information is critical, digital KMS platforms play a vital role in bridging knowledge gaps between researchers, extension workers, and farmers (FAO, 2022).

Digital knowledge management platforms have been shown to improve information dissemination, enable rapid response to emerging issues, and enhance farmer engagement through accessible and user-friendly interfaces (Tripathi et al., 2020). Furthermore, such systems support the integration of data from multiple sources, allowing for improved data surveillance, trend analysis, and decision support.

Despite these advancements globally, many organizations in developing countries, including Uganda, continue to rely on manual knowledge management practices which include paper-based reports, extension bulletins, and face-to-face interactions, which result in inefficiencies such as delayed information sharing, poor accessibility, and limited stakeholder engagement (Ikoja-Odongo & Ocholla, 2017). Consequently, the absence of robust digital knowledge management systems constrains the ability of these organizations to respond effectively in providing real time information.

In Uganda, the National Agricultural Research Organisation (NARO) plays a central role in generating and disseminating agricultural knowledge, including research on crop disease management. However, the institution's current knowledge management practices remain largely analogue, limiting timely access to critical information and reducing the effectiveness of advisory services. This challenge is particularly evident in the management of banana diseases such as Banana Bacterial Wilt (BBW) (Tinzaara et al. 2024), Sigatoka (Yonow et al. 2019), Fusarium Wilt (Panama Disease) (Ploetz, 2015). of different types of bananas such as the cooking bananas with various varities namely, Nakabululu, Nakitembe, Musakala, Nfuuka, Kisansa, Mpologoma, Kibuzi, Nsansa, Nakinyika, Namwezi (Tushemereirwe et al., 2004) where delays in managing information can lead to significant losses of knowledge within the Organization.

Therefore, the proposed digital knowledge management system for banana disease control specifically for cooking bananas (matooke) at NARO will modernize agricultural services by enabling real-time knowledge management, sharing and rapid response to farmer banana disease control needs, which will therefore be strengthening agricultural resilience.

1.1 Background of the Study

Conceptual Background

Digital Knowledge Management Systems (KMS) have transformed information management and sharing within NARO. These systems reduce duplication of tasks, promote innovation, and make knowledge easier to store, organize, and access Unlike traditional paper-based systems, digital KMS enable people to collaborate even when they are in different locations, can share knowledge in real time, and easily retrieve the information they need to make decisions. (Davenport & Prusak, 1998; Alavi & Leidner, 2001).

Digital knowledge management systems have increasingly been applied to improve information dissemination, advisory services, and user engagement. Digital knowledge management systems have evolved from conventional extension approaches to digital platforms such as mobile-based advisory services, online repositories, and decision-support systems (FAO, 2022). These platforms allow users, researchers, and extension workers to interact more effectively, access up-to-date information, and respond promptly to emerging challenges.

In knowledge-based institutions, the effective management of knowledge is essential for improving operational efficiency, collaboration, and support data-driven decision-making which improve service delivery. A digital knowledge management system (KMS) enables organizations to capture, organize, store, retrieve, and share knowledge through centralized digital platforms which support real-time access to information, reduce duplication of work, enhance institutional memory, and promote knowledge sharing among users regardless of location and time.

Organizations such as National Agricultural Research Organisation (NARO) are expected to adopt integrated digital systems that facilitate efficient knowledge flow which rely on digital technologies to manage large volumes of data and knowledge generated through research and extension activities. Researchers in knowledge management systems emphasize that effective KMS are critical tools for transforming organizational knowledge into accessible and usable information resources (Mutula, 2015; Twinomurinzi, 2020).

Research studies show that digital knowledge management systems in different sectors such as Education, Health, Business, Transport, and agriculture have been applied in several areas, including market research information, weather forecasting, and farming advisory services. For example, mobile-based services in Sub-Saharan Africa have helped farmers in the agricultural sector access important information such as recommended farming practices, input usage guidelines, and weather forecasts (African Development Bank, 2021). In addition, digital repositories have been used to store research findings and make them available to users whenever needed, improving access to information and supporting better decision-making (Tripathi et al., 2020).

However, the use of digital Knowledge Management Systems remains limited in many developing countries including Uganda where Some of the common challenges include inadequate digital infrastructure, low digital literacy among users, and the presence of multiple

independent systems that do not work together effectively (FAO, 2022). Many existing systems mainly focus on information sharing but do not allow users to interact, share experiences, or provide feedback which makes it difficult to capture valuable knowledge from the field and use it to improve services.

Another major issue, many organizations lack digital KMS that are specifically developed to meet their needs. Instead, they rely on small, independent technologies that are not fully integrated into their daily operations and Such systems often do not support the full cycle of knowledge management, which includes knowledge creation, storage, sharing, and effective utilization (Durst & Ferenhof, 2023).

Therefore, despite the significant potential of digital Knowledge Management Systems to improve information management, there remains a need to develop well-integrated, user-friendly, and organization-specific KMS. This study seeks to address this gap by developing a Digital Knowledge Management System to improve the National Agricultural Research Organizations (NARO) processes for managing knowledge related to banana disease control.

Institutional Background

The National Agricultural Research Organisation (NARO) is a government agency responsible for coordinating and conducting research aimed at supporting national development in Uganda. The organization was established in 1992 and later strengthened through the National Agricultural Research Act of 2005**,** which formalized its mandate to generate, manage, and disseminate knowledge and technologies. NARO operates under the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and functions as a network of research institutes located in different regions of the country (NARO, 2023).

NARO's structure includes both National Agricultural Research Institutes (NARIs) and Zonal Agricultural Research and Development Institutes (ZARDIs), which collectively conduct research of national and regional importance across different agro-ecological zones (NARO, 2024). These institutes are responsible for generating scientific knowledge, technologies, and innovations in areas such as crops, livestock, fisheries, forestry, and socio-economic research.

NARO is a knowledge-intensive organization that generates large volumes of data and information through research activities, laboratory experiments, field trials, and stakeholder engagements. The institution's mandate includes generating and disseminating agricultural knowledge and technologies to support national development and improve service delivery

(NARO, 2023), which makes the organization heavily dependent on effective information management systems to handle its knowledge assets.

In its operations, NARO has increasingly adopted Information and Communication Technology (ICT) tools such as databases, digital repositories, laboratory information systems, and online information hubs to support research and communication processes. However, despite these efforts, challenges still exist in integrating, organizing, and sharing knowledge across different departments and institutes.

Therefore, NARO provides an appropriate institutional environment for studying and developing a digital knowledge management system, as it is a data-driven organization that requires efficient systems for storing, retrieving, sharing, and preserving knowledge to support data driven decision-making and organizational performance.

1.2 Problem Statement

Despite the importance of timely and reliable knowledge in banana disease control, the National Agricultural Research Organisation (NARO) still relies on fragmented and partly manual knowledge management practices, including paper-based records, extension bulletins, standalone databases, and face-to-face information sharing. These approaches make it difficult to store, update, retrieve, and share banana disease knowledge efficiently, especially information related to disease diagnostics, research findings, and integrated management practices.

The absence of a centralized digital knowledge management system has resulted in slow information retrieval, duplication of data, limited collaboration among users, and the risk of losing valuable institutional knowledge. This affects the ability of researchers, extension officers, and other stakeholders to access accurate and timely information needed for decision-making and effective banana disease control.

Therefore, there is a need to develop a digital knowledge management system that can support the capture, storage, retrieval, sharing, and preservation of banana disease knowledge at NARO. Such a system will improve access to reliable information, enhance collaboration, reduce knowledge loss, and support timely responses to banana disease management needs.

1.3 Project Objectives

1.3.1 Overall objective

The overall objective of the project was to develop a digital knowledge management system for banana disease control, specifically for cooking banana (matooke), with emphasis on Kibuzi and Nakitembe varieties at the National Agricultural Research Organisation (NARO).

Table 1: Specific Objectives and Research Questions

Specific Objectives	Research Questions
To assess how cooking banana-related knowledge, including disease diagnostics and integrated management practices, is currently managed at NARO.	How is cooking banana-related knowledge, including disease diagnostics and integrated management practices, currently managed at NARO?
To identify requirements for a digital knowledge management system for cooking banana disease control at NARO.	What are the functional and non-functional requirements for developing a digital knowledge management system for cooking banana disease control at NARO?
To develop a digital knowledge management system for cooking banana disease control at NARO.	How can a digital knowledge management system for cooking banana disease control be designed and developed at NARO?
To test and validate the implemented knowledge management system for cooking banana disease control at NARO.	How effective is the developed digital knowledge management system in supporting the management of cooking banana disease control knowledge at NARO?

1.4. Scope of the Project

Contextual scope of the project

This project focused on the development of a Digital Knowledge Management System (KMS) for supporting the collection, storage, organization, and sharing of knowledge related to banana disease management within the National Agricultural Research Organisation (NARO). The

system would improve how research knowledge, extension information, and field data are managed and accessed by researchers, extension workers, and other stakeholders.

The system specifically supported knowledge related to banana (matooke) production in Uganda, which is a key staple crop in the country. The study considered major cooking banana varieties commonly grown in Uganda, including Mbwazirume, Nakitembe, Nfuuka, Mpologoma, Kibuzi, Musakala, Mbindi, Mbidde, Kisansa, Nakabululu, Nsansa, Nakinyika, Namwezi (Tushemereirwe et al., 2003; Karamura et al., 2008). These varieties form an important knowledge base for farmers and researchers in banana production systems.

The scope also covered key banana diseases affecting production and yield, which was included in the knowledge management system database. These diseases include Banana Xanthomonas Wilt (BXW), Black Sigatoka (Black Leaf Streak Disease), Fusarium Wilt (Panama disease), Banana Bunchy Top Disease (BBTD), Banana Streak Virus (BSV), Cigar End Rot, and Nematode infestations affecting roots and corms (Tripathi et al., 2009; Blomme et al., 2013; Ploetz, 2015).

The proposed system would focus on knowledge management functions such as enabling keyword-based search, and facilitating knowledge sharing among users thus improving information accessibility (NARO, 2023).

Time and Geographical scope

The project was executed within a three-month timeframe between April to June 2026.The project will encompass systems development and testing of the developed knowledge management system. It was carried out at the National Agricultural Research Organization Namulonge branch located along Gayaza-Zirobwe Road in Wakiso district, Busukuma sub-county, Namulonge village.

1.5 Significance of the Project

The project will address how organizational knowledge can be effectively captured, organized, shared, and reused through a digital platform within a research environment such as the National Agricultural Research Organisation (NARO).

The project will contribute to improving knowledge accessibility, retrieval, sharing and collaboration enhancing the ability of researchers, extension officers, and other stakeholders to

quickly access relevant and reliable information, which improves efficiency in knowledge use and decision support.

A well-structured KMS will support knowledge preservation and institutional memory which will enable users to contribute, update, and share knowledge in real time, reducing duplication of effort and promoting teamwork.

1.6 Definition of project key terms:

Knowledge Management (KM)

Knowledge Management refers to the systematic processes of capturing, organizing, storing, and retrieving research outputs generated such as laboratory findings, diagnostic protocols management recommendations across research stations for institutional use, enabling efficient internal access and decision-making.

Knowledge Management System (KMS)

A Knowledge Management System is a digital platform integrating tools for knowledge creation, capture, storage, retrieval, and application to support organizational learning and decision-making. (Durst & Ferenhof, 2023).

Digital Knowledge Management System

A digital platform designed for digitizing research knowledge from paper records, field notebooks, and scattered files into a single, searchable digital repository with structured indexing, user authentication, and retrieval capabilities.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature related to the development of a Digital Knowledge Management System for banana disease control at the National Agricultural Research Organisation (NARO). The review focuses on how agricultural knowledge is generated, stored, shared, retrieved, and applied in disease management. It also examines global trends in digital knowledge management systems, the African context of agricultural knowledge management, the role of digital systems in banana disease diagnostics and integrated disease management, system requirements for digital KMS development, and gaps that justify the need for a digital knowledge management system at NARO.

A literature review helps researchers to understand existing knowledge, identify gaps, avoid duplication, and position the current project within previous studies (Barry et al., 2022). In this project, the literature review is guided by the study objectives, namely: assessing current cooking banana-related knowledge management practices at NARO, identifying system requirements, developing a digital KMS, and testing and validating the system.

This section introduces the purpose of the literature review and links it directly to the project objectives. It shows that the review is not general, but focused on digital knowledge management for banana disease control.

2.2 Global Trends in Digital Knowledge Management Systems in Agriculture

Globally, digital knowledge management systems have become important tools for improving how organizations capture, organize, store, retrieve, share, and apply knowledge. A knowledge management system refers to an integrated platform that supports knowledge creation, storage, dissemination, and use for improved organizational learning and decision-making (Durst & Ferenhof, 2023). In agriculture, such systems are increasingly used to manage research outputs, extension information, pest and disease data, weather information, market information, and farmer advisory services.

The shift from manual to digital knowledge management has been influenced by the increasing volume of agricultural data generated through research, field trials, laboratory analysis, extension activities, and farmer feedback. Traditional paper-based systems are often slow, fragmented, and difficult to update. In contrast, digital KMS platforms allow users to access

information quickly, share knowledge across different locations, and preserve institutional knowledge for future use (Tripathi et al., 2020).

Digital systems used in agriculture include mobile advisory platforms, online repositories, decision-support systems, disease surveillance systems, databases, and digital extension platforms. These tools support real-time knowledge sharing among researchers, extension workers, farmers, policymakers, and other agricultural stakeholders. According to FAO (2022), digital agricultural platforms improve access to advisory information and strengthen communication between knowledge producers and end users.

Digital knowledge management systems are also important in supporting innovation because they allow different actors to exchange experiences, lessons, and technical information. For example, agricultural researchers can upload research findings, extension workers can retrieve advisory materials, and farmers can access practical recommendations. This reduces delays in information sharing and improves decision-making in agricultural production and disease control.

Summary of key points: Globally, agriculture is increasingly adopting digital KMS platforms to improve knowledge storage, retrieval, sharing, and decision-making. These systems are replacing fragmented manual approaches and creating faster links between research, extension, and practice.

2.3 Agricultural Knowledge Management in the African Context

In Africa, agriculture remains a major source of food, employment, and livelihoods, making effective agricultural knowledge management essential for productivity and resilience. Knowledge management in African agriculture involves the generation, documentation, sharing, and use of information among researchers, extension workers, farmers, input suppliers, policymakers, and development partners. Agricultural Knowledge and Innovation Systems (AKIS) have been used to explain how these actors interact to generate and apply agricultural knowledge (Arundhathi et al., 2025).

Despite the growing importance of digital systems, many agricultural institutions in Africa still face challenges in managing knowledge effectively. These challenges include inadequate digital infrastructure, limited internet connectivity, low digital literacy among some users, weak integration of information systems, and continued reliance on printed reports and manual

records (FAO, 2022). As a result, useful agricultural knowledge is often scattered across departments, projects, computers, paper files, and individual staff members.

Research institutions in Africa also generate large amounts of scientific knowledge through laboratory work, field trials, research reports, extension manuals, and technical bulletins. However, this knowledge is not always organized in a way that allows easy retrieval and use. Wamukoya (2022) notes that reliance on traditional storage systems such as printed reports and decentralized documentation often leads to fragmentation, duplication, and loss of information.

Another major challenge in the African context is the failure to capture tacit knowledge. Tacit knowledge refers to practical knowledge gained through experience, field observation, and professional judgment (Johannessen, 2022). In banana disease management, this may include practical skills used by researchers and extension workers to identify symptoms, interpret disease patterns, and recommend context-specific control measures. When such knowledge is not documented, institutions risk losing valuable expertise when experienced staff retire, transfer, or leave the organization.

Summary of key points: In Africa, agricultural research institutions generate important knowledge, but much of it remains fragmented, poorly digitized, and difficult to retrieve. The limited capture of tacit knowledge also weakens institutional memory and reduces the practical use of research outputs.

2.4 Banana Disease Knowledge Management in Agricultural Research Institutions

Cooking bananas are an important staple crop in East and Central Africa and play a major role in food security, income generation, and rural livelihoods (Khakasa et al., 2024). In Uganda, cooking bananas such as matooke are widely consumed and economically important. However, banana production is affected by several diseases, including Banana Bacterial Wilt, Black Sigatoka, Fusarium Wilt, Banana Bunchy Top Disease, Banana Streak Virus, Cigar End Rot, and nematode infestations (Tinzaara et al., 2024; Ploetz, 2015).

Banana disease knowledge includes information on disease symptoms, causes, diagnostic procedures, laboratory results, field observations, resistant varieties, management practices, and farmer advisory recommendations. This knowledge is generated through scientific research, laboratory testing, field trials, farmer engagement, and extension activities. Agricultural research institutions such as NARO play an important role in generating and disseminating this knowledge.

In many agricultural research institutions, banana disease knowledge is documented in research reports, laboratory protocols, diagnostic manuals, technical bulletins, extension guides, and field trial records. However, these documents may be stored in different departments, offices, computers, databases, or physical files. When knowledge is not centrally stored, users may struggle to locate accurate and updated information, especially during disease outbreaks.

Effective banana disease knowledge management requires a system that can capture both scientific and practical knowledge. Scientific knowledge may include laboratory findings, diagnostic protocols, and disease surveillance data. Practical knowledge may include field observations, farmer experiences, and extension workers' recommendations. A well-developed digital KMS can bring these different types of knowledge together in one searchable platform.

Summary of key points: Banana disease control depends on accurate and accessible knowledge. However, in many research institutions, this knowledge is scattered across different sources, making it difficult for users to retrieve and apply it effectively.

2.5 Digital Knowledge Management for Disease Diagnostics and Integrated Disease Management

Disease diagnostics is a central component of banana disease control because accurate diagnosis helps researchers and extension workers identify disease causes and recommend appropriate management measures. Diagnostic knowledge may include symptom descriptions, photographs, laboratory procedures, pathogen identification methods, and control guidelines. In banana production, field diagnosis often involves observing symptoms such as wilting, leaf spots, discoloration, fruit abnormalities, and plant decline, while laboratory diagnosis may involve microbiological or molecular testing.

Norton and Awang (2020) observe that extension workers often face challenges in accessing updated diagnostic materials. When diagnostic knowledge is difficult to access, diseases may be misidentified, leading to inappropriate recommendations and increased crop losses. This makes knowledge retrieval an important function in any system designed for banana disease control.

Integrated disease management involves combining different practices to reduce disease incidence and improve crop health. These practices may include field sanitation, use of resistant varieties, removal of infected plants, tool sterilization, proper agronomic practices, biological control, and chemical control where appropriate (Sharma & Bochalya, 2025). In banana

systems, integrated management is important because no single control method is sufficient for all diseases and production conditions.

Digital KMS platforms can support disease diagnostics and integrated disease management by storing diagnostic protocols, disease images, treatment recommendations, research findings, and extension materials in a centralized database. They can also support keyword search, user authentication, data updates, reporting, and knowledge sharing among researchers and extension officers. This improves access to reliable information and strengthens decision-making.

Summary of key points: Digital KMS platforms can improve banana disease control by making diagnostic information and integrated disease management practices easier to store, retrieve, update, and share.

2.6 Comparison of Existing KMS Implementations in Agriculture

Different forms of digital knowledge management systems have been implemented in agriculture to support information access, advisory services, research documentation, and decision-making. These systems vary in purpose, users, functions, and limitations.

Type of KMS implementation	**Main users**	**Key functions**	**Strengths**	**Limitations**
Mobile-based agricultural advisory systems	Farmers, extension workers, agricultural officers	Provide farming tips, weather updates, pest and disease alerts, and input use guidelines	Easy to access through phones; supports quick dissemination of information	May exclude users with low digital literacy or poor network access
Online agricultural repositories	Researchers, students, policymakers, extension workers	Store research reports, publications, manuals, and technical bulletins	Preserves institutional knowledge and improves access to research outputs	Often less interactive and may not capture field-based tacit knowledge

Type of KMS implementation	Main users	Key functions	Strengths	Limitations
Disease surveillance databases	Researchers, plant health officers, extension workers	Record disease incidence, location, severity, and spread	Supports disease monitoring and planning	Requires regular data updates and reliable field reporting
Decision-support systems	Researchers, extension officers, farmers	Provide diagnosis support and management recommendations	Helps users make informed decisions based on available data	May require technical expertise and accurate data inputs
Laboratory information systems	Laboratory staff, researchers, plant pathologists	Manage samples, test results, diagnostic records, and laboratory workflows	Improves accuracy, traceability, and organization of diagnostic data	May be limited to laboratory use and not integrated with extension information
Digital knowledge-sharing platforms	Researchers, extension workers, farmers, policymakers	Enable knowledge exchange, feedback, collaboration, and learning	Encourages interaction among stakeholders and supports communities of practice	May be difficult to sustain without active participation and institutional support

From the comparison above, existing agricultural KMS implementations contribute to knowledge storage, advisory services, disease monitoring, and decision-making. However, many systems focus on one function only, such as advisory communication, document storage, or disease surveillance. Few systems integrate research outputs, diagnostic knowledge, integrated management practices, user interaction, and reporting in one platform.

Summary of key points: Existing agricultural KMS platforms provide useful lessons, but many are limited in scope. There is need for an integrated system that combines storage, retrieval, diagnostics, management recommendations, reporting, and knowledge sharing for banana disease control.

2.7 System Requirements for Developing a Digital Knowledge Management System

Developing an effective digital knowledge management system requires clear identification of system requirements. Requirements define what the system should do, how it should operate, and the conditions under which it should function. Umar and Lano (2024) explain that requirements engineering involves identifying, documenting, analyzing, and managing system needs throughout the system development process.

System requirements are commonly divided into functional and non-functional requirements. Functional requirements describe the specific services the system must provide, while non-functional requirements describe the quality attributes of the system, such as speed, security, reliability, usability, and accuracy.

For a digital KMS for banana disease control, functional requirements may include user registration and authentication, data entry, storage of banana disease information, uploading of diagnostic protocols, keyword-based searching, report generation, feedback mechanisms, and access control. These functions allow authorized users to capture, retrieve, update, and share knowledge within the system.

Non-functional requirements are equally important because they determine whether the system can be used effectively. The system should process information quickly, provide reliable access to stored data, protect information from unauthorized alteration, maintain data accuracy, and present results in a consistent and understandable format. Mutula (2015) emphasizes that the success of digital information systems in African institutions depends on reliability, security, and accessibility.

Summary of key points: A digital KMS for banana disease control must have clear functional and non-functional requirements. It should support knowledge storage, retrieval, reporting, security, reliability, and ease of use.

2.8 Development, Testing, and Validation of Digital Knowledge Management Systems

The development of a digital knowledge management system requires a structured system development approach. System development involves planning, analysis, design, implementation, testing, and evaluation. Pearlson (2024) identifies technology planning, software selection, implementation, and evaluation as key stages in developing electronic information systems.

The planning stage involves identifying the need for the system, defining the project scope, and determining the resources required. In the context of NARO, planning focuses on understanding the need for a centralized platform that can manage banana disease knowledge. The analysis stage involves examining the current system, identifying weaknesses, and determining user requirements. This includes assessing existing documentation practices, databases, information-sharing methods, and user needs.

The design stage translates system requirements into a system blueprint. It includes database design, user interface design, input and output design, and security design. Tools such as data flow diagrams and entity relationship diagrams can be used to show how information will move through the system and how data will be organized.

Testing and validation are important because they ensure that the system works according to user requirements. Unit testing checks individual components, integration testing checks whether different parts of the system work together, system testing checks the whole system, and compatibility testing checks whether the system works on different platforms. Validation confirms that the system meets user needs and produces accurate outputs.

Summary of key points: Digital KMS development should follow a structured process from planning to validation. Testing ensures that the system is functional, secure, reliable, and appropriate for users.

2.9 Benefits of Digital Knowledge Management Systems in Agricultural Research

Digital knowledge management systems offer several benefits to agricultural research institutions. First, they improve information accessibility by allowing users to retrieve knowledge from a centralized platform rather than searching through scattered paper files, reports, and databases. This saves time and improves decision-making.

Second, digital KMS platforms support knowledge preservation and institutional memory. Knowledge generated by researchers, extension workers, and field officers can be stored and reused even when individual staff members leave the organization. This reduces the risk of losing valuable institutional knowledge.

Third, digital KMS platforms improve collaboration among users. Researchers, extension officers, plant pathologists, ICT staff, and field officers can share information more easily when knowledge is stored in one system. This strengthens coordination and reduces duplication of effort.

Fourth, digital systems support timely response to agricultural problems. In banana disease control, quick access to diagnostic protocols and management recommendations can help users respond faster to disease outbreaks. This is important because delays in accessing information may lead to the spread of diseases and increased crop losses.

Finally, digital knowledge management systems support reporting, monitoring, and learning. Stored data can be used to generate reports on disease trends, knowledge use, and management practices. This can support planning, research prioritization, and extension programming.

Summary of key points: Digital KMS platforms improve access to information, preserve institutional knowledge, strengthen collaboration, support timely disease response, and improve reporting in agricultural research institutions.

2.10 NARO-Specific Knowledge Management Gaps

NARO is a knowledge-intensive agricultural research organization that generates large volumes of data and information through research, laboratory activities, field trials, extension engagement, and institutional reporting. Its mandate includes generating and disseminating agricultural technologies and knowledge to support national development and improved agricultural productivity.

Despite this mandate, the management of banana disease knowledge at NARO faces several gaps. First, knowledge is fragmented across paper records, reports, extension bulletins, standalone databases, laboratory records, and individual staff expertise. This makes it difficult for users to access complete and updated information from one source.

Second, retrieval of information is slow because users may have to search through physical files, scattered digital folders, or consult specific individuals. This can delay decision-making, especially when urgent disease control information is required.

Third, there is a risk of knowledge loss because some practical knowledge remains with individual researchers, extension officers, and field staff. When experienced staff leave the organization, their undocumented knowledge may not be preserved.

Fourth, collaboration among users is limited when knowledge is not stored and shared through an integrated platform. Researchers may generate disease control information, but extension workers and other users may not access it quickly or in a format that supports field application.

These gaps show that NARO requires a digital KMS that can centralize banana disease knowledge, improve retrieval, support knowledge sharing, preserve institutional memory, and strengthen decision-making. The system should be designed to manage knowledge related to cooking banana diseases, diagnostics, integrated management practices, and user feedback.

Summary of key points: The main NARO-specific gaps are fragmented storage, slow retrieval, limited collaboration, and risk of knowledge loss. These gaps directly justify the need for a centralized digital KMS for banana disease control.

2.11 Research Gap

The reviewed literature shows that digital knowledge management systems have been widely recognized for improving information storage, access, sharing, collaboration, and decision-making in agriculture. Studies also show that digital platforms can support agricultural advisory services, disease surveillance, research documentation, and integrated disease management.

However, much of the existing literature focuses on general digital agricultural platforms, mobile advisory systems, institutional repositories, and information systems in libraries or academic institutions. Limited attention has been given to integrated digital knowledge management systems specifically designed for agricultural research institutions dealing with banana disease control.

In addition, many existing systems do not fully integrate disease diagnostics, integrated management practices, research outputs, user authentication, reporting, and knowledge-sharing functions in one platform. There is also limited evidence on digital KMS platforms designed

specifically to manage cooking banana disease knowledge within Uganda's agricultural research environment.

Therefore, this project addresses this gap by developing a Digital Knowledge Management System for banana disease control at NARO. The system is intended to support the capture, storage, retrieval, sharing, and preservation of knowledge related to cooking banana disease diagnostics and integrated management practices.

Summary of key points: The literature confirms the value of digital KMS platforms, but reveals a gap in integrated systems for banana disease control within agricultural research institutions such as NARO. This gap provides the justification for the current project.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the methodology that was used in the development of the Digital Knowledge Management System for banana disease control at the National Agricultural Research Organisation (NARO). It describes research design, area of study, sampling methods, data collection methods and tools, data quality control measures, ethical considerations, and anticipated limitations of the study. The chapter also explains the system planning and analysis process used during the development of the knowledge management system.

The methodology adopted in this study integrates both systems development approaches and qualitative data collection methods to obtain relevant information from NARO staff and institutional documents. These methods enabled the researchers to understand how banana disease knowledge is currently generated, stored, shared, and utilized by asking questions within NARO and to identify the requirements for developing an effective digital knowledge management system.

3.2 System Planning and Analysis

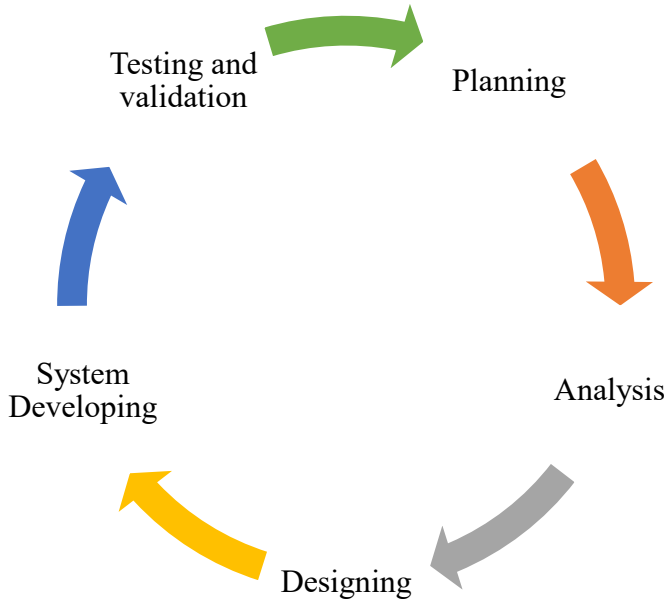
This study adopted the Waterfall Model as the software development approach for developing the Digital Knowledge Management System for banana disease control at NARO. The Waterfall Model was considered appropriate because the project had clearly defined objectives and system requirements that could be gathered, documented, analyzed, designed, implemented, tested, and validated in a sequential manner. Since the system was intended to support specific knowledge management functions such as storage, retrieval, sharing, reporting, and user authentication, it was necessary to follow a structured development process that allowed each phase to be completed before moving to the next.

The Waterfall Model was preferred over other software development approaches such as Agile and Prototyping because this project was academic, time-bound, and required systematic documentation at every stage. Agile methods are useful where requirements change frequently and where continuous user feedback is expected throughout development. However, this project required a more predictable and controlled process because the researchers first had to understand the existing knowledge management practices at NARO, identify system

requirements, design the system, develop it, and then test and validate it. Similarly, prototyping is useful where users are not clear about the system they want, but in this project, the main system functions were already guided by the project objectives and the identified knowledge management gaps.

The Waterfall Model was also suitable because it supports proper documentation, which is important in institutional systems and academic projects. Each stage produced outputs that guided the next stage. For example, system planning helped to define the project scope, requirements analysis identified user and system needs, system design produced the logical and physical design of the system, system development implemented the design, and testing and validation confirmed whether the system met the intended requirements. Therefore, the Waterfall Model provided a clear, organized, and manageable framework for developing the proposed Digital Knowledge Management System.

Figure 1: A Cycle Showing Waterfall Model



Source: Adapted from Van Casteren (2017)

The project team interacted with relevant stakeholders at NARO including researchers, extension officers, data managers, and information technology personnel to gather requirements for the knowledge management system. Interviews were conducted to supplement information gathered from institutional documents reviewed. The system analyst

worked closely with stakeholders to develop a system requirements specification document that guided the system development process.

The aim of the requirements analysis is to ensure technical feasibility, quality assurance, and identification of potential risks that could affect the successful implementation of the knowledge management system.

For this study, the vision is to develop a centralized digital knowledge management system that supported the capture, storage, retrieval, and sharing of banana disease knowledge within NARO. The system enabled researchers, extension officers, and other stakeholders to easily access research findings, disease diagnostic protocols, and integrated disease management practices related to cooking bananas.

a) Determining Present Status

A system study was conducted to assess the current status of knowledge management practices at NARO. This involved collecting information about existing processes used for managing agricultural research knowledge.

The assessment involved gathering information about:

- Research documentation practices at NARO
- Existing databases and digital repositories
- Knowledge sharing practices among researchers and extension workers
- Types of banana disease research data generated
- Current methods used for storing and retrieving research outputs

The sources of data included:

- NARO research reports
- Banana disease diagnostic manuals
- Laboratory protocols and field trial records
- Institutional policies and operational guidelines
- Annual reports and agricultural extension publications

This assessment helped identify the gaps in the current knowledge management system and determine the improvements required.

b) Requirement Determination

Requirement determination involves identifying the functional and non-functional requirements of the proposed knowledge management system. By comparing the current knowledge management practices at NARO with the objectives of the proposed system, the researchers identified the system features required to support effective management of banana disease knowledge.

The requirements included functionalities related to:

- Storage of research outputs
- Documentation of disease diagnostics
- Retrieval of integrated disease management practices
- Knowledge sharing among researchers and extension officers
- Data analysis and reporting

c) Feasibility

After system analysis and design have been completed, a feasibility study was conducted to determine whether the proposed system can be successfully implemented.

The feasibility study addressed the following questions:

- Is the proposed system possible?
- Is it necessary?
- What other options are available?
- Is it affordable?

The results of the feasibility study were compiled into a feasibility report which guided system development decisions.

d) Technology Plan

A technology plan was developed to guide the implementation of the system. The plan included:

- Vision, goals and objectives of the system
- Components required to achieve the system vision
- System specifications and technical requirements

- Financial estimates and resource requirements
- Implementation strategy and action plan
- Project timeline

Selection and Acquisition of the System

The system was developed through an in-house development approach where the system is designed and developed locally to meet the specific knowledge management needs of NARO. The system may also integrate modular technologies and open-source tools that support digital repositories and database management.

3.3 Requirements Gathering

In gathering system requirements, the project team reviewed existing institutional documents from NARO. These documents provide valuable information about how banana disease knowledge is generated and managed within the organization.

The documents to be reviewed include:

- NARO research reports on banana diseases
- Laboratory diagnostic protocols
- Field trial reports
- Agricultural extension manuals
- Integrated disease management guidelines
- Institutional policy documents
- Research publications and technical bulletins

To complement document analysis, the researchers used several data collection methods including interviews, questionnaires, and observation.

3.3.1 Interview Method

Chand (2025) defines an interview as a conversation between a researcher and a participant aimed at obtaining detailed information about a research topic. Interviews enabled researchers to explore participants' experiences, perceptions, and insights regarding a particular issue.

In this study, interviews were conducted with:

- Agricultural researchers at NARO

- Plant pathologists involved in banana disease research
- Extension officers
- Data managers and information system administrators

These interviews provided information about the current methods used for managing banana disease knowledge and the challenges associated with existing knowledge management practices.

3.3.1.1 Interview Guide

The main tool that was used during the interview process is an interview guide. An interview guide is a structured list of questions prepared by the researcher to guide the discussion during the interview and ensure that all relevant information required for the study is collected (Naz, 2022). The interview guide helps to maintain focus on the objectives of the study while allowing respondents the freedom to explain their experiences and views in detail.

The interview guide for this study contained both open-ended and semi-structured questions focusing on key areas such as Current practices of managing banana disease knowledge at NARO, Methods used for storing and retrieving research information, Knowledge sharing practices among researchers and extension officers, Challenges faced in accessing banana disease information, Requirements for developing a digital knowledge management system and the technical and operational expectations for the proposed system.

The interview guide was administered through face-to-face interviews with selected respondents at their respective workplaces within NARO. In cases where face-to-face meetings may not be possible, interviews may be conducted through virtual communication platforms or telephone conversations. Each interview is expected to last approximately 30-45 minutes, depending on the availability of the respondent and the depth of the responses provided.

The interview participants were purposively selected from staff members at NARO who are directly involved in banana disease research, knowledge management, and information systems. These participants include: Agricultural researchers working on banana disease research, Plant pathologists involved in disease diagnosis and laboratory analysis, Agricultural extension officers responsible for disseminating research findings to farmers and Data managers responsible for storing and managing research information (*See appendix I*).

The interview process included signing a consent statement by each participant before the interview is conducted. This consent statement explained the purpose of the study, assure

participants that their responses was kept confidential, and inform them that participation is voluntary. It also gave participants the right to withdraw from the study at any time without any penalty. (*See appendix III*).

3.3.2 Document Analysis

Document analysis is a qualitative research method used to examine and interpret written documents in order to gain understanding about a particular phenomenon (Armstrong, 2021). In this study, document analysis was used to review institutional documents related to banana disease research and knowledge management at NARO.

The documents to be analyzed include research reports, diagnostic manuals, laboratory protocols, and agricultural extension publications. Analyzing these documents helped identify the types of knowledge resources generated within NARO and how they are currently managed.

3.3.2.1 Document Review Guide

The main tool that was used during document analysis is a Document Review Guide. A document review guide is a structured checklist used by researchers to systematically examine and extract relevant information from written documents (Pati & Lorusso, 2018). The document review guide helped to identify key information such as Types of banana disease knowledge generated at NARO, Methods used for documenting research findings, Existing documentation and record-keeping practices, Current knowledge storage systems and repositories, Information sharing mechanisms used within NARO and the gaps and challenges in the current knowledge management practices. The guide ensure that document analysis is conducted in a consistent and organized manner while focusing on information relevant to the objectives of the study.

The document review guide was used to systematically examine selected institutional documents available at NARO, we reviewed both printed and digital documents stored in offices, institutional repositories, research databases, and archives. According to Cardno (2018) analysis of these documents helps the researchers identify existing knowledge resources, assess current documentation practices, determine gaps in the management of banana disease information, and establish requirements for the proposed Digital Knowledge Management System.

The following types of institutional documents was reviewed when available: NARO research reports on banana diseases, Banana disease diagnostic manuals, Laboratory diagnostic protocols, Field trial reports, Integrated disease management guidelines, Agricultural extension manuals and publications, Institutional policy documents related to research and knowledge management, ICT and data management guidelines, Annual reports and technical bulletins among others (*See appendix II*).

3.4 Population of the Study

The population of a study refers to the entire group of individuals, objects, institutions, or units from which the researcher intends to collect information and draw conclusions. In this study, the population comprised staff and system users within the National Agricultural Research Organisation (NARO) who are involved in the generation, storage, management, sharing, retrieval, and use of banana disease control knowledge.

The study population specifically included NARO researchers, plant pathologists, laboratory staff, agricultural extension officers, information management staff, ICT personnel, research assistants, and field officers. These categories of respondents are relevant because they directly participate in banana disease research, disease diagnosis, field data collection, extension communication, documentation of integrated disease management practices, and management of institutional knowledge resources.

The accessible population therefore was drawn from NARO staff and related users who have practical knowledge and experience in banana disease control, especially in relation to cooking banana varieties and diseases such as Banana Bacterial Wilt, Black Sigatoka, Fusarium Wilt, Banana Bunchy Top Disease, and other banana production constraints. This population is appropriate because the proposed Digital Knowledge Management System is intended to support the capture, storage, retrieval, and sharing of banana disease knowledge within NARO.

Therefore, the target population for the study consisted of N = 83 NARO staff/system users. This total population formed the basis for determining the sample size of the study using an appropriate sample size determination method, such as Krejcie & Morgan’s table or another rational sampling approach.

3.5 Sample Size

A sample size refers to the number of respondents selected from the total study population to participate in a research study. In this study, the sample size was determined from a target population of 83 respondents.

Using Krejcie and Morgan's sample size determination formula, the sample size is calculated as follows:

$$s = \frac{X^2 NP(1-P)}{d^2(N-1) + X^2 P(1-P)}$$

Where:

$s =$ required sample size

$X^2 = 3.841$

$N = 83$

$P = 0.5$

$d = 0.05$

Substituting into the formula:

$$s = \frac{3.841 \times 83 \times 0.5(1-0.5)}{0.05^2(83-1) + 3.841 \times 0.5(1-0.5)}$$

$$s = 68.4$$

Therefore, the required sample size was approximately 68 respondents. The sample was proportionately distributed across the different respondent categories as shown below:

Table 2: Population of the Study

Category of respondents	Population	Sample size
NARO researchers and laboratory staff	18	15
Agricultural extension officers	15	12
Information management and ICT staff	10	8
Research assistants and field officers/system users	40	33
Total	**83**	**68**

The respondents were selected purposively because the study requires participants who have direct knowledge and experience in banana disease research, knowledge management,

extension communication, ICT support, and system use. This enabled the researchers to obtain relevant and detailed information needed for developing the proposed Digital Knowledge Management System for banana disease control at NARO.

3.6 Sampling Procedure

The study used purposive sampling to select respondents from NARO staff and system users who were directly involved in banana disease research, disease diagnostics, extension communication, field data collection, ICT support, and knowledge management. Purposive sampling was chosen because the study required information from respondents with specific knowledge, experience, and responsibility related to banana disease control and the management of agricultural research knowledge. Since not all staff at NARO are involved in banana disease research or knowledge management, random sampling would not have guaranteed that the selected respondents had the relevant information needed for the project.

The respondents included NARO researchers and laboratory staff, agricultural extension officers, information management and ICT staff, research assistants, and field officers/system users. These categories were selected because they interact with banana disease knowledge at different stages. Researchers and laboratory staff generate and validate scientific knowledge, extension officers disseminate knowledge to farmers, ICT and information management staff understand system and data management needs, while research assistants and field officers collect and use field-level disease information.

Purposive sampling was therefore appropriate because it enabled the researchers to obtain detailed and relevant information from knowledgeable participants. However, the method may introduce selection bias because respondents are chosen based on the researchers' judgment rather than by chance. This means that some views from other staff who were not selected may have been left out. To reduce this bias, the study included different categories of respondents involved in banana disease knowledge management and used multiple data collection methods, including interviews, document analysis, and observation. This helped to capture varied perspectives and improve the credibility of the findings.

3.7 System Design

Once the system requirements have been identified and verified, the next phase involves designing the system architecture. System design specifies both software and hardware requirements required to develop the knowledge management system.

The system design phase defined:

- System architecture
- Database design
- User interface design
- Data input and output mechanisms
- Security and authentication mechanisms

The goal of this phase is to ensure that the system architecture supports efficient knowledge storage, retrieval, and sharing.

3.8 Data Quality Control Issues

Data quality refers to the extent to which data accurately represent the real-world phenomena they describe (Zhang, 2016). Ensuring high-quality data is essential in research studies to improve the reliability and validity of research findings. To ensure data quality, the researchers applied methodological triangulation, which involves using multiple data collection methods to study the same phenomenon. The study therefore used interviews, document analysis, and observation to collect data.

We also ensured that the language used in questionnaires and interview guides is simple and clear so that respondents can easily understand the questions. According to (Dingre, 2022), data quality control procedures are important for detecting missing information, identifying errors during data entry, detecting duplicates, and ensuring data consistency.

A pilot test of the questionnaire was conducted before the actual data collection in order to eliminate uncertainties and improve clarity.

3.9 Data Analysis

Data collected from the study were analyzed using both quantitative and qualitative methods. This was because the study generated both numerical data and descriptive information from respondents and institutional documents. Quantitative data were obtained mainly from structured responses, respondent background information, and responses related to knowledge management practices, system requirements, and user needs. These data were coded, entered, organized, and analyzed using descriptive statistics.

Descriptive statistical analysis involved the use of frequencies, percentages, tables, and charts to summarize the responses. Frequencies were used to show how many respondents gave

particular responses, while percentages were used to show the proportion of respondents in each category. Tables were used to present data in an organized format, while charts were used to provide visual summaries of major findings. Where necessary, means were used to summarize responses measured using rating scales, especially those related to the importance of system requirements, user satisfaction, and perceptions of current knowledge management practices.

Qualitative data were obtained from interviews, observation, and document analysis. These data were analyzed using thematic analysis. The researchers first read through the interview responses, observation notes, and reviewed documents to become familiar with the data. The data were then coded by identifying key words, phrases, and ideas related to the study objectives. Similar codes were grouped into broader themes such as current knowledge management practices, challenges in storage and retrieval, knowledge sharing gaps, system requirements, user expectations, and benefits of the proposed system.

Thematic analysis helped the researchers to identify patterns and meanings in the qualitative responses. For example, responses relating to scattered records, standalone databases, paper-based storage, and reliance on individual staff knowledge were grouped under the theme of fragmented knowledge storage. Responses relating to delays in accessing information, difficulty in locating reports, and dependence on face-to-face consultation were grouped under slow knowledge retrieval. These themes were then interpreted in relation to the project objectives and used to guide the design and development of the Digital Knowledge Management System.

Data from document analysis were also reviewed to identify the types of banana disease knowledge generated at NARO, the current methods of documentation, existing gaps in storage and retrieval, and the kind of information that needed to be included in the proposed system. Observation data were used to support and confirm findings from interviews and document review. The use of quantitative and qualitative analysis enabled the researchers to present both statistical summaries and detailed explanations of the findings.

3.10 System Development

During system development, the system architecture was implemented based on the system design specifications. The system included several data processing components as shown below.

Data store	Description
Research data	Store banana disease research findings
Diagnostic records	Store disease diagnostic protocols and laboratory results
Management practices	Stores integrated disease management recommendations
Reports	Generates analytical reports on disease trends and management practices
User management	Manages system users and authentication

Data flow refers to how information moves through the system from the point of data entry to the generation of system outputs.

The Digital KMS allowed users to log in using authorized credentials, submit research data, access diagnostic protocols, and retrieve disease management recommendations. The system consisted of both front-end and back-end components. The front end provided user interfaces for data entry and retrieval, while the back end managed database storage, authentication, and information processing.

3.11 Testing and Validation

System testing was conducted to ensure that the developed system performs according to the defined system requirements. Testing involved verifying that system components function correctly and that the system produces accurate outputs.

Different forms of testing were conducted including:

- Unit testing
- Integration testing
- System testing
- Compatibility testing

The system was tested using sample banana disease data to ensure that the system correctly stores, retrieves, and processes research information.

3.12 Ethical Issues

Ethical considerations are important in research studies involving human participants. According to Alhabsi (2024), ethical research requires respect for participants' rights, dignity, and confidentiality. The study adhered to the following ethical principles:

Confidentiality

All information provided by respondents was treated confidentially. Personal identities of participants were not disclosed in the research report.

Permission from Authorities

Permission to conduct the study was obtained from relevant authorities at NARO before data collection begins.

Integrity and Respect

We ensured honesty and transparency throughout the research process. Data was accurately recorded and analyzed without falsification or misrepresentation.

Informed Consent and Voluntary Participation

Participants were informed about the purpose of the study before participating. Their participation was voluntary and they had the right to withdraw from the study at any time.

3.13 Limitations of the Study

The study encountered several limitations including:

- Some respondents were reluctant to share institutional information due to confidentiality concerns.
- Some staff members had limited time to participate in interviews due to their research responsibilities.
- Delays occurred in returning questionnaires from respondents.
- Limited access to some institutional documents may affect the completeness of document analysis.

Despite these limitations, we made every effort to ensure that sufficient data is collected to support the objectives of the study.

CHAPTER FOUR: PRESENTATION AND DISCUSSION OF FINDINGS

4.0 Introduction

This chapter presents a comprehensive analysis, presentation, and discussion of findings obtained from the study conducted at the National Agricultural Research Organisation (NARO) between April and June 2026. The purpose of this study was to develop a digital knowledge management system for banana disease control, specifically for cooking banana (matooke) varieties, with emphasis on Kibuzi and Nakitembe.

The chapter is structured according to the four study objectives and corresponding research questions outlined in Chapter One. Data was collected from 68 respondents (from a target population of 83) using semi-structured interviews, document analysis of institutional records, and observation of existing knowledge management practices, as described in Chapter Three. Quantitative data were analyzed using descriptive statistics (frequencies, percentages, means), while qualitative data from interviews were analyzed thematically.

The findings are presented using frequency tables, bar charts, pie charts, photographs (where available), and narrative descriptions with direct quotations from respondents, followed by a discussion relating findings to the literature reviewed in Chapter Two.

4.1 Demographic Characteristics of Respondents

Understanding the background of respondents is essential for interpreting the validity and relevance of the findings. This section presents the distribution of respondents by category, length of experience, gender, and educational level.

4.1.1 Category of Respondents

As indicated in Chapter Three, the target population comprised 83 NARO staff, with a sample size of 68 respondents determined using Krejcie and Morgan's formula. Table 4.1 shows the distribution of respondents by category, and Figure 4.1 presents this data visually.

Table 3: Category of Respondents

Category of Respondents	Population	Sample Size	Frequency (Actual)	Percentage (%)
NARO Researchers and Laboratory Staff	18	15	15	22.1
Agricultural Extension Officers	15	12	12	17.6
Information Management and ICT Staff	10	8	8	11.8
Research Assistants and Field Officers/System Users	40	33	33	48.5
Total	**83**	**68**	**68**	**100**

Source: Primary Field Data, 2026

The total number of actual respondents = 68.

The percentages in the table were calculated using the formula:

$$\textbf{Percentage (\%)} = \frac{\textbf{Frequency (Actual)}}{\textbf{Total Number of Respondents}} \times 100$$

Table 4.1 shows that out of 68 respondents, the majority were research assistants and field officers (33, 48.5%), followed by researchers and laboratory staff (15, 22.1%), extension officers (12, 17.6%), and ICT and information management staff (8, 11.8%). This distribution is significant because Research assistants and field officers are responsible for day-to-day data collection, field observations, and initial documentation of disease occurrences. Their dominant representation ensures that the study captured practical, ground-level perspectives on knowledge management challenges. Researchers and laboratory staff provide insights into how scientific knowledge is generated, validated, and documented. Their representation (22.1%) is adequate to understand knowledge creation processes. Extension officers (17.6%) bridge the gap between research and farmers. Their input was critical for understanding how knowledge is disseminated and what barriers exist in reaching end-users. ICT staff (11.8%), though the smallest group, provided essential technical perspectives on infrastructure, system requirements, and feasibility. This balanced representation across all categories enhances the

validity of the findings, as multiple stakeholder perspectives were captured (Casteel & Bridier, 2021).

4.1.2 Gender of Respondents

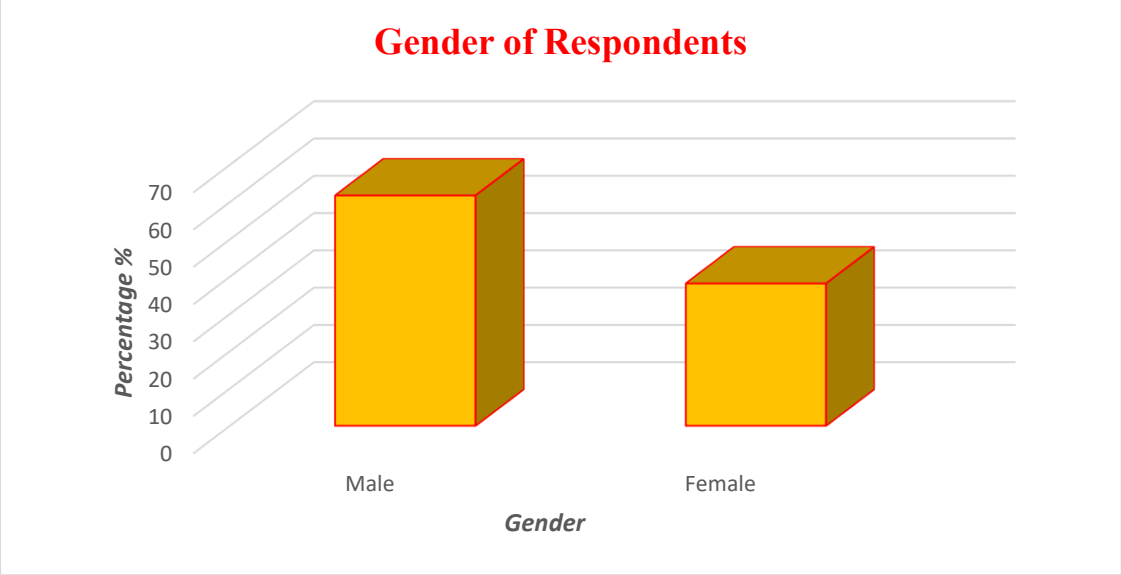
Respondents were asked to indicate their gender to understand the gender distribution among NARO staff involved in banana disease knowledge management. Table 4.2 and Figure 4.2 present the findings.

Table 4: Gender of Respondents

Gender	Frequency	Percentage (%)
Male	42	61.8
Female	26	38.2
Total	**68**	**100**

Source: Primary Field Data, 2026

Figure 2: Gender of Respondents



The findings indicate that the majority of respondents were male (61.8%), while females constituted 38.2%. This gender distribution reflects the broader trend in agricultural research institutions in Uganda, where male staff still dominate technical and research positions, although female participation has been increasing in recent years (UBOS, 2024). The presence of 26 female respondents (38.2%) provided adequate representation of female perspectives on knowledge management needs.

4.1.3 Length of Experience in Banana-Related Work

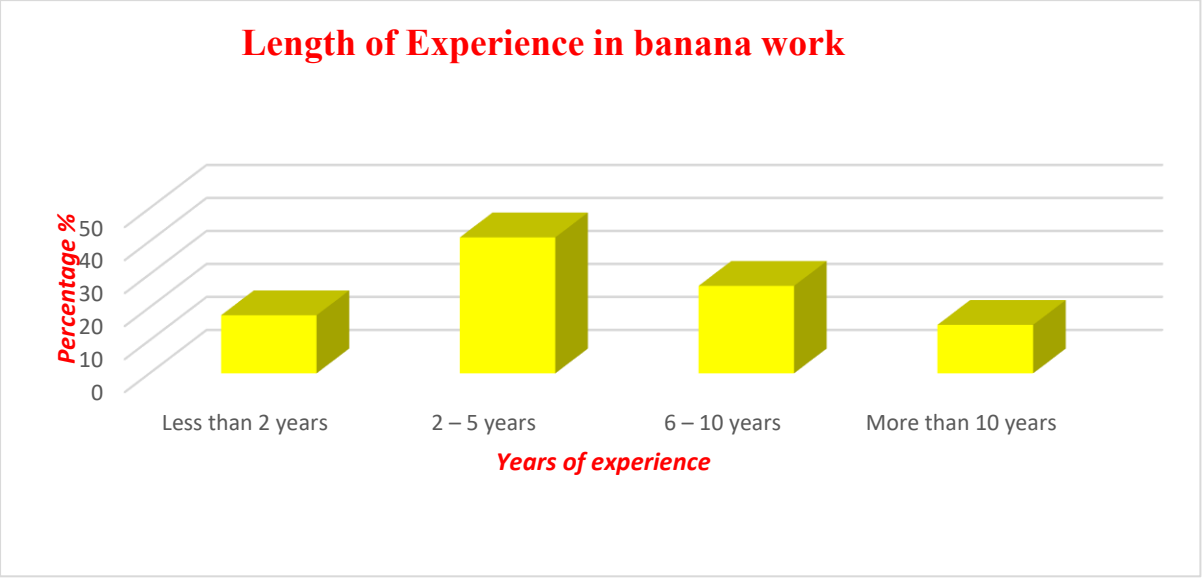
Respondents were asked about the duration of their involvement in banana-related research, extension, or information management. This variable is important because more experienced staff have deeper insights into knowledge management challenges and requirements. Table 4.3 and Figure 4.3 present the findings.

Table 5: Length of Experience in Banana-Related Work

Years of Experience	Frequency	Percentage (%)	Cumulative Percentage
Less than 2 years	12	17.6	17.6
2 – 5 years	28	41.2	58.8
6 – 10 years	18	26.5	85.3
More than 10 years	10	14.7	100
Total	**68**	**100**	

Source: Primary Field Data, 2026

Figure 3: Length of Experience in banana work



The Cumulative Percentage formula is:

Cumulative Percentage = Previous Cumulative Percentage + Current Percentage

The findings indicate that the majority of respondents (41.2%) had between 2 and 5 years of experience, followed by those with 6-10 years (26.5%). Only 14.7% had more than 10 years of

experience. This distribution suggests that NARO has a relatively young workforce with moderate levels of experience and this has two implications where younger staff may be more receptive to digital technologies and innovative knowledge management solutions (Twinomurinzi, 2020). A Challenge of limited number of highly experienced staff (14.7% with >10 years) means that significant tacit knowledge resides with a small group of senior researchers. If this knowledge is not systematically captured, NARO risks losing valuable institutional memory when these staff retire or leave. This finding reinforces the need for a digital KMS that can capture and preserve tacit knowledge (Johannessen, 2022).

4.1.4 Educational Level of Respondents

Respondents were also asked about their highest level of education to assess digital literacy and capacity to use a digital KMS. Table 4.4 presents the findings.

Table 6: Educational Level of Respondents

Educational Level	Frequency	Percentage (%)
Diploma	8	11.8
Bachelor's Degree	35	51.5
Master's Degree	20	29.4
PhD	5	7.4
Total	**68**	**100**

Source: Primary Field Data, 2026

The majority of respondents (51.5%) held a Bachelor's degree, followed by those with a Master's degree (29.4%). Only 7.4% held a PhD, while 11.8% had a Diploma. This educational profile suggests that most NARO staff have the basic digital literacy required to use a digital knowledge management system, as university education typically includes basic computer and internet skills. However, the presence of Diploma holders (11.8%) indicates that training programs should be designed to accommodate varying levels of digital proficiency.

4.2 Current Management of Cooking Banana-Related Knowledge at NARO

Objective 1: To assess how cooking banana-related knowledge including disease diagnostics and integrated management practices are currently managed at NARO.

This section presents findings on the types of knowledge generated, documentation methods, storage systems, and knowledge sharing practices at NARO.

4.2.1 Types of Banana Disease Knowledge Generated at NARO

Respondents were asked to identify the types of knowledge related to banana disease control that are generated at NARO. Multiple responses were allowed. Table 4.5 and Figure 4.5 present the findings.

Table 7: Types of Banana Disease Knowledge Generated at NARO

Type of Knowledge	Frequency	Percentage (%)	Rank
Disease diagnostic protocols	58	85.3	1
Field trial results	52	76.5	2
Laboratory research findings	48	70.6	3
Integrated disease management practices	45	66.2	4
Pest and disease surveillance data	40	58.8	5
Farmer advisory materials	35	51.5	6
Training manuals and extension bulletins	32	47.1	7
Variety characterization data	28	41.2	8
Economic impact assessments	20	29.4	9

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

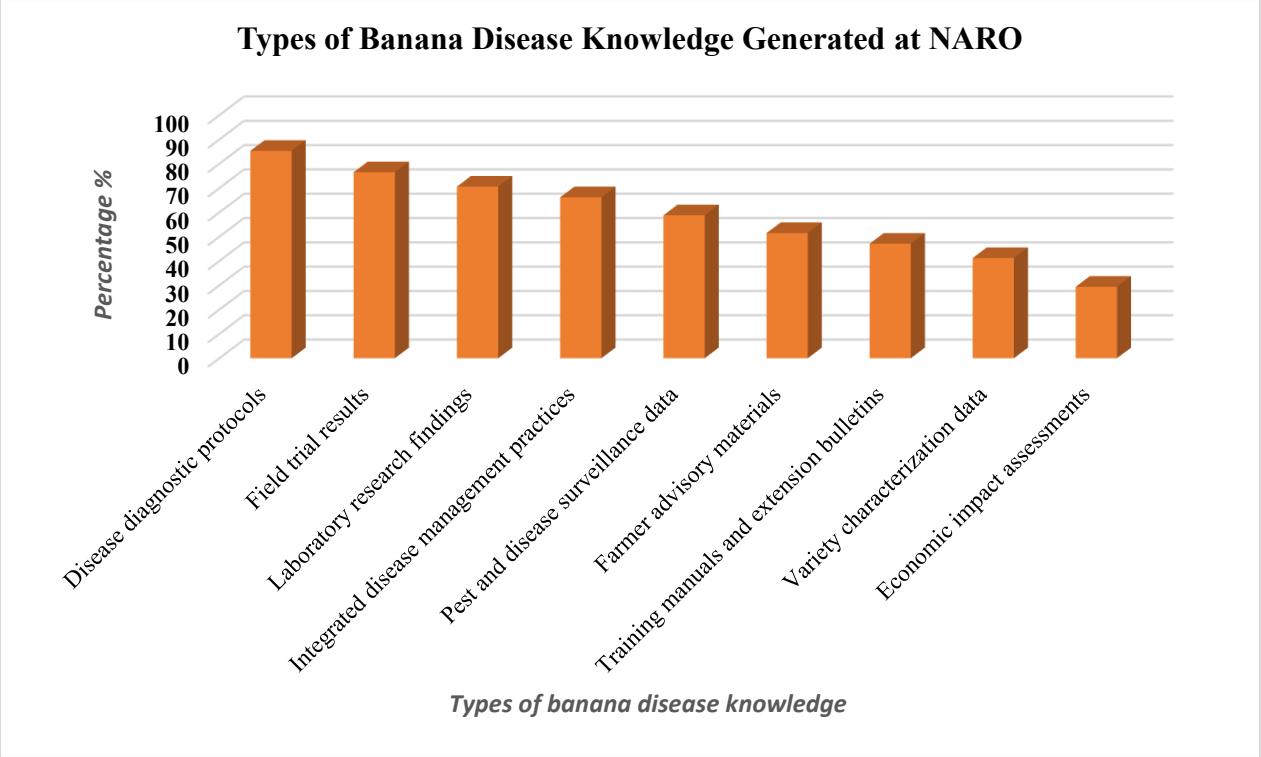


Figure 4: Types of Banana Disease Knowledge Generated at NARO

The findings reveal that disease diagnostic protocols (85.3%) and field trial results (76.5%) were the most commonly generated types of knowledge. This aligns with NARO's mandate as a research institution focused on generating scientific evidence for agricultural development (NARO, 2023). Diagnostic protocols are essential for accurate disease identification, which is the first step in effective disease management (Tinzaara et al., 2024).

However, the lower frequencies for farmer advisory materials (51.5%) and training manuals (47.1%) indicate a significant knowledge translation gap. While NARO generates substantial scientific knowledge, less of this knowledge is being converted into farmer-friendly formats. One senior researcher explained during an interview:

> *"We produce high-quality research, but we don't always have the time or resources to package it for farmers. Extension materials require a different skill set – simpler language, more visuals, and practical recommendations. That's not always our focus."* (Researcher 3, Interview, May 2026)

This finding is consistent with Akuku et al. (2021), who noted that agricultural research institutions in East Africa generate substantial research outputs but face challenges in converting them into practical extension materials. The proposed digital KMS should include functionality to support the creation and dissemination of farmer-friendly knowledge products.

4.2.2 Commonly Documented Banana Diseases

Respondents were asked to identify the banana diseases that are frequently documented and researched at NARO. Table 4.6 and Figure 4.6 present the findings.

Table 8: Commonly Documented Banana Diseases at NARO

Banana Disease	Frequency	Percentage (%)	Rank
Banana Bacterial Wilt (BXW)	62	91.2	1
Black Sigatoka (Black Leaf Streak)	55	80.9	2
Fusarium Wilt (Panama Disease)	48	70.6	3
Banana Bunchy Top Disease (BBTD)	38	55.9	4
Banana Streak Virus (BSV)	30	44.1	5
Nematode infestations	28	41.2	6
Cigar End Rot	20	29.4	7
Banana Weevils (pest, not disease)	15	22.1	8

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

Figure 5: Commonly Documented Banana Diseases at NARO

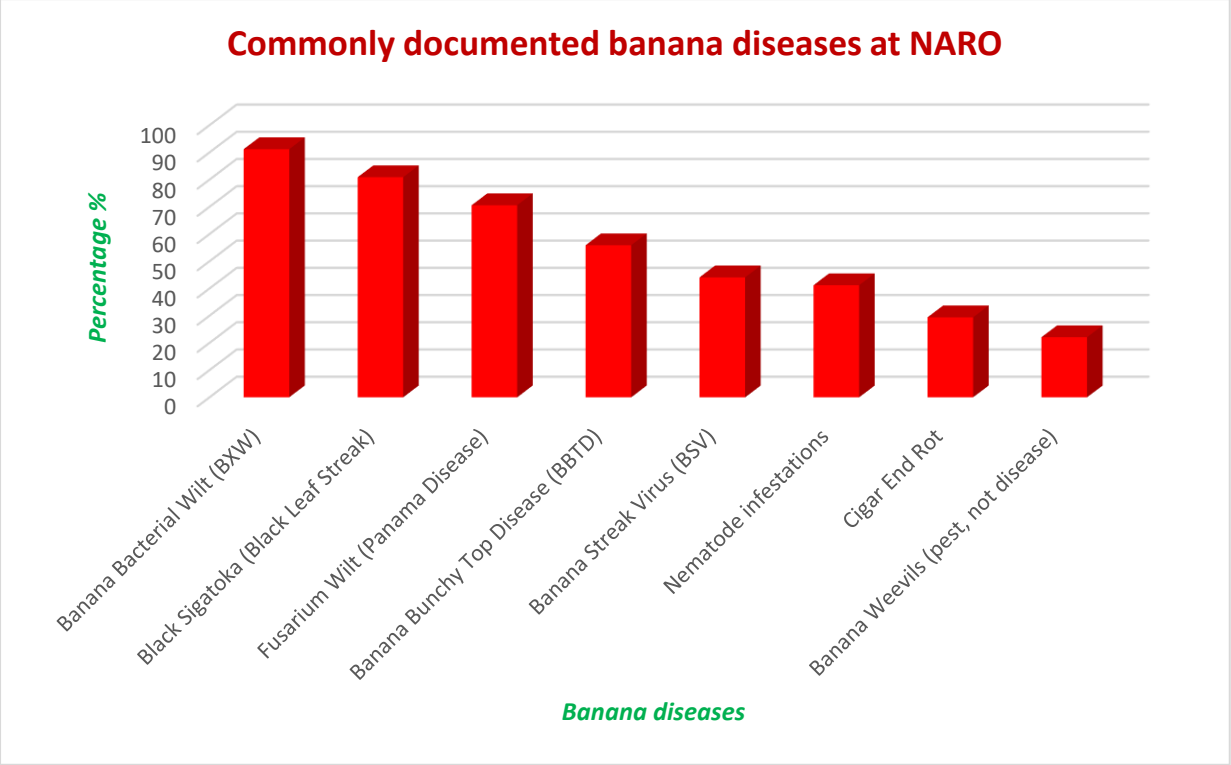


Table 4.6 shows that Banana Bacterial Wilt (BXW) (91.2%) was the most commonly documented disease, followed by Black Sigatoka (80.9%) and Fusarium Wilt (70.6%). This finding is consistent with Tinzaara et al. (2024), who identified BXW as the most devastating banana disease in East and Central Africa, causing yield losses of up to 100% in affected farms.

An extension officer provided context:

"When BXW broke out in our district, farmers lost entire plantations. Since then, NARO has invested heavily in BXW research – diagnostic protocols, resistant varieties, and management strategies. That's why we have so much documentation on it." (Extension Officer 2, Interview, May 2026)

The high documentation for Black Sigatoka (80.9%) is also expected, as this fungal disease has become increasingly problematic due to changing climatic conditions (Yonow et al., 2019). The lower documentation for diseases such as Cigar End Rot (29.4%) and Banana Weevils (22.1%) may reflect either lower economic impact or research prioritization based on available funding.

Implication for the Digital KMS: The system must accommodate knowledge on all documented diseases, with particular attention to BXW, Black Sigatoka, and Fusarium Wilt, which have the most extensive knowledge resources.

4.2.3 Cooking Banana Varieties Covered in Knowledge Resources

Regarding the cooking banana varieties covered in existing knowledge resources, Table 4.7 and Figure 4.7 present the findings.

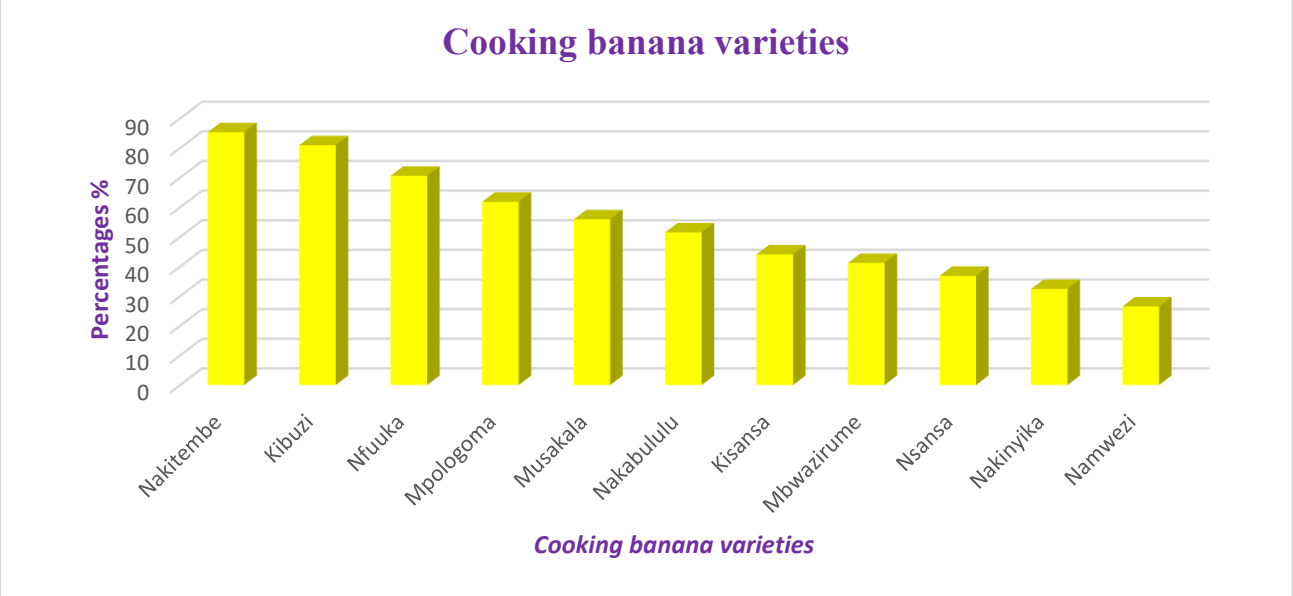
Table 9: Cooking Banana Varieties Commonly Covered in Knowledge Resources

Variety	Frequency	Percentage (%)	Rank
Nakitembe	58	85.3	1
Kibuzi	55	80.9	2
Nfuuka	48	70.6	3
Mpologoma	42	61.8	4
Musakala	38	55.9	5
Nakabululu	35	51.5	6

Variety	Frequency	Percentage (%)	Rank
Kisansa	30	44.1	7
Mbwazirume	28	41.2	8
Nsansa	25	36.8	9
Nakinyika	22	32.4	10
Namwezi	18	26.5	11

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

Figure 6: Cooking Banana Varieties Commonly Covered in Knowledge Resources



The findings indicate that Nakitembe (85.3%) and Kibuzi (80.9%) the two varieties emphasized in this study – are well-covered in existing knowledge resources. This confirms that NARO has generated substantial knowledge on these economically important varieties, which are preferred by farmers for their cooking quality, taste, and marketability (Tushemereirwe et al., 2004; Karamura et al., 2008).

However, varieties such as Namwezi (26.5%) and Nakinyika (32.4%) have relatively lower coverage. A researcher explained:

"Nakitembe and Kibuzi are the most popular varieties among farmers in central Uganda, where NARO Namulonge is located. So, most of our research has focused on these. Varieties

like Namwezi are more common in western Uganda, and we have less documentation on them." (Researcher 2, Interview, May 2026)

Implication for the Digital KMS: The system should be designed to accommodate knowledge on all cooking banana varieties, even those with currently limited documentation, to promote more balanced knowledge generation and preservation.

4.2.4 Current Methods of Knowledge Storage

One of the most critical findings of this study relates to how banana disease knowledge is currently stored at NARO. Table 4.8 and Figure 4.8 present the findings.

Table 10: Current Knowledge Storage Methods

Storage Method	Frequency	Percentage (%)	Rank
Paper-based files and reports	60	88.2	1
Standalone computer databases (individual computers)	42	61.8	2
Spreadsheets (Excel)	38	55.9	3
Institutional digital repository (limited use)	25	36.8	4
External hard drives/USB storage	22	32.4	5
Cloud-based storage (Google Drive, Dropbox)	10	14.7	6
Integrated digital knowledge management system	0	0.0	7

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

Photo 1: Paper-based research records at NARO Namulonge.



The findings reveal that paper-based files and reports (88.2%) remain the dominant storage method at NARO, followed by standalone databases (61.8%) and spreadsheets (55.9%). Most significantly, no respondent (0%) indicated the existence of an integrated digital knowledge management system.

This finding confirms the problem statement that NARO relies on fragmented, manual, and standalone systems for managing banana disease knowledge. An ICT staff member described the situation:

"We have research data scattered across different offices, personal computers, external drives, and paper files. Some researchers store data on their laptops. When they travel or leave the

organization, that data becomes inaccessible. We have no central system where everyone deposits their findings." (ICT Officer 1, Interview, May 2026)

The heavy reliance on paper-based storage (88.2%) is particularly concerning because paper records deteriorate over time, are vulnerable to damage from humidity, fire, or pests, and cannot be searched efficiently. As noted by Mutula and Wamukoya (2007) and Ikoja-Odongo and Ocholla (2017), many African agricultural institutions still depend on paper-based documentation systems, leading to inefficiencies in knowledge retrieval and sharing.

Implication for the Digital KMS: There is an urgent need for a centralized digital repository that can: (1) digitize existing paper records, (2) provide structured storage for new research outputs, and (3) enable searchable access to all knowledge resources.

4.2.5 Knowledge Sharing Practices Among Stakeholders

Respondents were asked how banana disease knowledge is currently shared among researchers, extension officers, and other stakeholders. Table 4.9 and Figure 4.9 present the findings.

Table 11: Knowledge Sharing Practices

Sharing Method	Frequency	Percentage (%)	Rank
Face-to-face meetings/workshops	55	80.9	1
Printed extension bulletins	48	70.6	2
Email communication	42	61.8	3
Telephone calls	38	55.9	4
Physical visits to research stations	35	51.5	5
WhatsApp/other messaging platforms	28	41.2	6
Institutional website	15	22.1	7
Digital repository	8	11.8	8

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

Figure 7: Knowledge Sharing Practices



The findings indicate that face-to-face interactions (80.9%) and printed bulletins (70.6%) are the predominant methods of knowledge sharing. While these methods have their advantages (personal interaction, relationship building), they also have significant limitations:

1. **Limited reach** – Only staff who attend meetings or receive printed materials benefit.
2. **No real-time access** – Information is shared at specific times, not available on demand.
3. **No searchability** – Once a meeting ends or a bulletin is misplaced, the knowledge is difficult to retrieve.

One extension officer expressed frustration:

"When I am in the field and a farmer asks me a specific question about disease management for Kibuzi variety, I cannot call a researcher every time. I need a system where I can search for that information myself, anytime, even on my phone." (Extension Officer 4, Interview, May 2026)

The low usage of digital repositories (11.8%) and the institutional website (22.1%) indicates a significant gap in leveraging digital platforms for knowledge dissemination. This finding aligns with Ikoja-Odongo and Ocholla (2017), who noted that agricultural knowledge sharing in Uganda still relies heavily on traditional, manual approaches.

4.3 Challenges in Current Knowledge Management Approaches at NARO

Objective 2: To identify challenges existing with NARO's current knowledge management approaches for cooking banana type specifically Kibuzi and Nakitembe varieties.

This section presents findings on challenges related to knowledge storage, retrieval, sharing, and collaboration.

4.3.1 Challenges in Storing Banana Disease Knowledge

Respondents were asked to identify the challenges they face when storing banana disease knowledge. Table 4.10 and Figure 4.10 present the findings.

Table 12: Challenges in Storing Banana Disease Knowledge

Challenge	Frequency	Percentage (%)	Rank
Fragmentation of information across multiple locations	55	80.9	1
Risk of data loss due to paper deterioration	52	76.5	2
Lack of centralized digital repository	50	73.5	3
Duplication of information	45	66.2	4
Inadequate ICT infrastructure	42	61.8	5
Limited digitization of historical records	38	55.9	6
Lack of standardized documentation formats	35	51.5	7
No backup system for digital files	30	44.1	8

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

Qualitative Findings – Verbatim Quotes:

A researcher described the fragmentation problem:

"Our research findings are scattered across different offices, personal computers, and paper files. When someone leaves, we often lose valuable data. Last year, a senior researcher retired, and we discovered that many of his field notes were stored only on his personal laptop, which was not backed up." (Researcher 5, Interview, May 2026)

A laboratory technician added:

"Paper records from the 1990s are still sitting in boxes in a storage room. Some are already eaten by insects or faded by humidity. If we don't digitize them soon, that knowledge will be lost forever." (Laboratory Staff 2, Interview, May 2026)

A photograph showing deteriorating paper records in a storage room at NARO.



Photo 2: Deteriorating paper records, highlighting the risk of data loss (cited by 76.5% of respondents)

Discussion:

The finding that fragmentation of information (80.9%) is the top storage challenge aligning with Reznicek (2020), who noted that fragmentation across departments leads to duplication and difficulty in locating relevant knowledge in real time. The risk of data loss due to paper deterioration (76.5%) is particularly urgent, as many historical research records are at risk of permanent loss.

4.3.2 Challenges in Retrieving Banana Disease Information

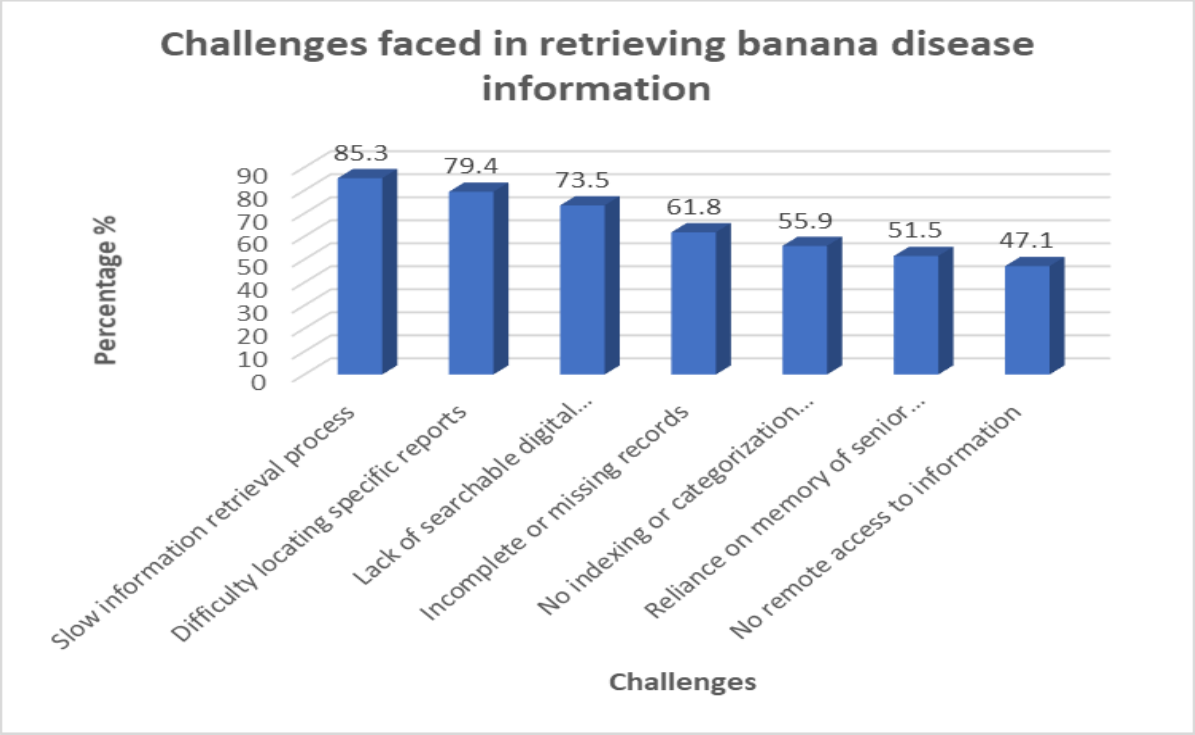
Respondents were asked about the challenges they face when trying to retrieve banana disease information. Table 4.11 and Figure 4.11 present the findings.

Table 13: Challenges in Retrieving Banana Disease Information

Challenge	Frequency	Percentage (%)	Rank
Slow information retrieval process	58	85.3	1
Difficulty locating specific reports	54	79.4	2
Lack of searchable digital database	50	73.5	3
Incomplete or missing records	42	61.8	4
No indexing or categorization system	38	55.9	5
Reliance on memory of senior staff	35	51.5	6
No remote access to information	32	47.1	7

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

Figure 8: Challenges in Retrieving Banana Disease Information



An extension officer explained the urgency of retrieval challenges:

"When a farmer reports a disease outbreak, I need quick access to diagnostic guidelines. But with the current system, it can take hours or even days to find the right information. By then,

the disease may have already spread to neighboring farms." (Extension Officer 1, Interview, May 2026)

A research assistant described the reliance on senior staff:

"If you need to find a specific research report from 2015, you often have to ask one of the senior researchers who remembers where it was filed. If they are not available, you are stuck. We need a system that doesn't rely on people's memory." (Research Assistant 3, Interview, May 2026)

Discussion:

The finding that slow retrieval processes (85.3%) and difficulty locating specific reports (79.4%) are major challenges highlighting the urgency of developing a digital KMS that enables rapid information retrieval. This is particularly critical during disease outbreaks when timely access to diagnostic and management information can mean the difference between containing a disease and losing the entire plantations (Tinzaara et al., 2024; FAO, 2022).

4.3.3 Challenges in Knowledge Sharing and Collaboration

Respondents also identified challenges related to knowledge sharing and collaboration. Table 4.12 presents these findings.

Table 14: Challenges in Knowledge Sharing and Collaboration

Challenge	Frequency	Percentage (%)	Rank
Limited collaboration across departments	52	76.5	1
No platform for real-time knowledge exchange	48	70.6	2
Geographic distance between research stations	45	66.2	3
Lack of incentive for knowledge sharing	38	55.9	4
Hierarchical organizational culture	35	51.5	5
Limited digital literacy among some staff	32	47.1	6

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

Qualitative Findings – Verbatim Quotes:

An ICT staff member noted:

"Researchers at Namulonge may have solved a problem that researchers at another station are still struggling with, but there is no easy way for them to share that knowledge. Everyone works in silos." (ICT Officer 2, Interview, May 2026)

A researcher commented on the lack of incentives:

"There is no formal recognition or reward for sharing knowledge. So, people tend to keep their data to themselves until they publish a paper. That culture needs to change, but a digital system can help by making sharing easier and more visible." (Researcher 4, Interview, May 2026)

These findings are consistent with Sseguya et al. (2017), who noted that weak knowledge-sharing mechanisms and organizational culture hinder effective knowledge utilization in African agricultural organizations. The proposed digital KMS should include features that encourage and reward knowledge sharing, such as user profiles, contribution tracking, and collaborative spaces.

4.4 Requirements for a Digital Knowledge Management System at NARO

Objective 3: To identify requirements for a digital knowledge management system for cooking banana disease control at NARO.

This section presents findings on functional requirements, non-functional requirements, and user/operational requirements.

4.4.1 Functional Requirements

Respondents were asked to identify the features that the proposed digital KMS should have. Table 4.13 and Figure 4.12 present the functional requirements.

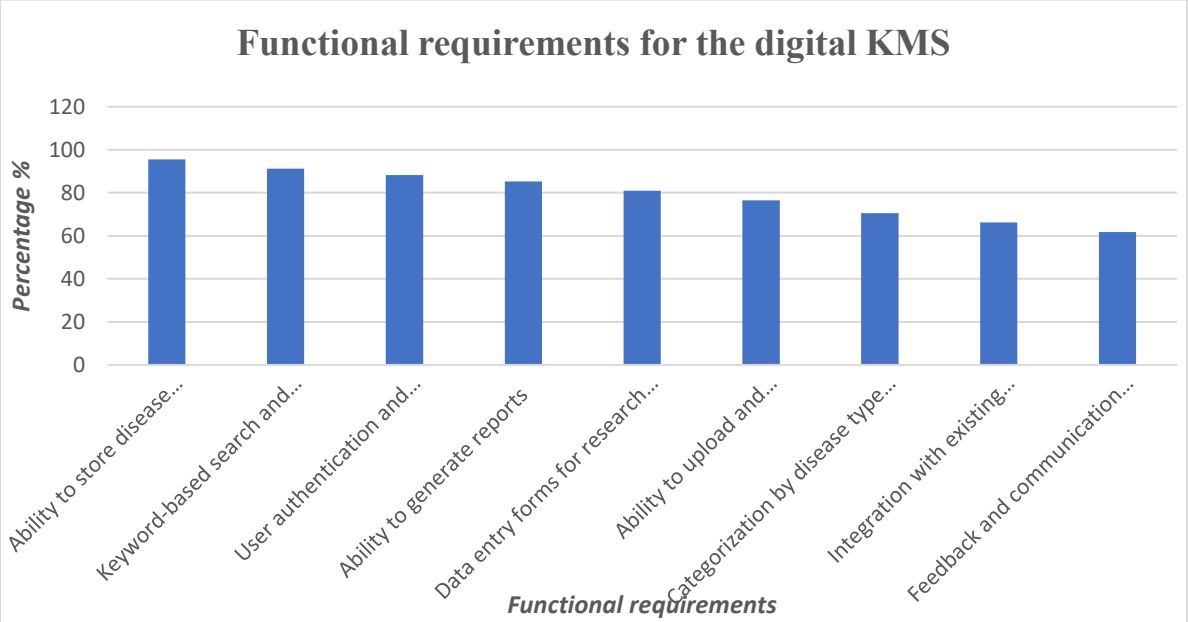
Table 15: Functional Requirements for the Digital KMS

Functional Requirement	Frequency	Percentage (%)	Rank
Ability to store disease diagnostic protocols	65	95.6	1
Keyword-based search and query functionality	62	91.2	2
User authentication and authorization	60	88.2	3
Ability to generate reports	58	85.3	4

Functional Requirement	Frequency	Percentage (%)	Rank
Data entry forms for research findings	55	80.9	5
Ability to upload and download documents	52	76.5	6
Categorization by disease type and variety	48	70.6	7
Integration with existing databases	45	66.2	8
Feedback and communication features	42	61.8	9

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

Figure 9: Functional Requirements for the Digital KMS



A researcher emphasized the importance of search functionality:

"We need a system where I can type 'Fusarium wilt Kibuzi' and immediately see all related research, diagnostic guides, and management recommendations. Not just documents, but synthesized knowledge." (Researcher 1, Interview, May 2026)

The finding that storage of diagnostic protocols (95.6%) and keyword-based search (91.2%) where the most highly prioritized functional requirements aligns with Durst and Ferenhof (2023), who emphasized that effective KMS must support the capture and retrieval of specialized knowledge. User authentication (88.2%) is also critical to ensure that sensitive research data is only accessible to authorized personnel.

4.4.2 Non-Functional Requirements

Respondents were asked about the quality attributes that the system should possess. Table 4.14 presents the non-functional requirements.

Table 16: Non-Functional Requirements

Non-Functional Requirement	Frequency	Percentage (%)	Rank
Fast information processing speed	60	88.2	1
Data security and integrity	58	85.3	2
Reliability (system availability when needed)	55	80.9	3
User-friendly interface	52	76.5	4
Consistent output format	48	70.6	5
Scalability (ability to grow with more data)	40	58.8	6
Compatibility with different devices	38	55.9	7

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

The findings show that fast processing speed (88.2%) and data security (85.3%) were the most cited non-functional requirements. This is consistent with Mutula (2015), who argued that the success of digital information systems in African institutions depends on their ability to provide reliable and secure access to information resources. An ICT NARO officer emphasized: *"The system must be secure because research data is sensitive. But it must also be fast – researchers will not use a slow system."*

4.4.3 User and Operational Requirements

Respondents provided additional requirements related to system usage and operations, as summarized in Table 4.15.

Table 17: User and Operational Requirements

Requirement	Frequency	Percentage (%)	Rank

System should be accessible online (web-based)	55	80.9	1
Training for users before system deployment	52	76.5	2
Simple and intuitive interface for non-technical users	50	73.5	3
Offline access capabilities for field staff	42	61.8	4
Mobile-friendly design	40	58.8	5
Multilingual support (English and local languages)	35	51.5	6
Helpdesk and technical support	32	47.1	7

Source: Primary Field Data, 2026 (Multiple responses allowed, N=68)

The majority of respondents (80.9%) preferred a web-based system accessible online, while 61.8% also desired offline capabilities for field staff who may not always have internet connectivity. A NARO extension officer explained: *"When I am in the field, internet is not always reliable. The system should allow me to collect data offline and synchronize later."* This finding is consistent with Tripathi et al. (2020), who noted that digital agricultural platforms should accommodate varying connectivity conditions.

4.5 Development and Implementation of the Digital Knowledge Management System

Objective 3: To develop a digital knowledge management system for cooking banana disease control at NARO.

Based on the requirements identified, the research team developed a web-based digital knowledge management system prototype. This section presents the system architecture, features, and screenshots.

4.5.1 System Architecture and Design

The system was developed using the Waterfall Model as described in Chapter Three. The system architecture comprised the following components:

1. Front-end: Web-based user interface developed using HTML5, CSS3, and JavaScript, with responsive design for mobile and desktop access.

2. Back-end: MySQL database management system for storing research outputs, diagnostic protocols, and user information.
3. Authentication Module: Role-based access control for researchers, extension officers, and administrators.
4. Search Module: Keyword-based search functionality with filters for disease type, banana variety, and document category.
5. Reporting Module: Automated generation of disease reports and knowledge summaries.

4.5.2 System Features Implemented

Based on the functional requirements identified, the following features were implemented:

1. **User Registration and Login**: Secure authentication for authorized users (meets requirement: user authentication – 88.2%).
2. **Knowledge Repository**: Centralized storage for research reports, diagnostic protocols, field trial data, and management guidelines (meets requirement: storage of diagnostic protocols – 95.6%).
3. **Search and Retrieval**: Keyword search with filters for disease, variety, and document type (meets requirement: keyword search – 91.2%).
4. **Data Entry Forms**: Structured forms for researchers and field officers to submit new knowledge (meets requirement: data entry forms – 80.9%).
5. **Report Generation**: Automated generation of disease trend reports and knowledge summaries (meets requirement: report generation – 85.3%).
6. **Admin Dashboard**: System administration and user management functions.

4.6 Discussion of Findings

This section discusses the key findings in relation to the literature reviewed in Chapter Two and the research objectives.

4.6.1 Current Knowledge Management Practices

The findings revealed that NARO still relies predominantly on paper-based and manual knowledge management practices (88.2% of respondents), with no integrated digital KMS

currently in place. This finding is consistent with Ikoja-Odongo and Ocholla (2017), who observed that agricultural knowledge management in Uganda remains largely analogue, limiting timely access to critical information. The fragmentation of knowledge across multiple locations and formats (80.9%) was identified as a major challenge, verifying Reznicek (2020) who noted that information fragmentation leads to duplication and difficulty in knowledge retrieval.

The study also found that face-to-face interactions (80.9%) and printed bulletins (70.6%) remain the dominant knowledge sharing methods. While these methods are valuable for relationship building, they are insufficient for real-time information dissemination during disease outbreaks. This finding aligns with the FAO (2022) observation that digital platforms enable real-time communication between researchers and end-users, a capability that is absent in NARO's current system.

4.6.2 Challenges in Knowledge Management

The study identified slow information retrieval (85.3%) and difficulty locating specific reports (79.4%) as critical challenges. These inefficiencies have direct consequences for disease management, as delays in accessing diagnostic and management information can lead to increased crop losses (Tinzaara et al., 2024). The lack of a centralized, searchable digital repository (73.5%) emerged as a fundamental gap that the proposed system seeks to address.

Additionally, limited collaboration across departments (76.5%) and the absence of a platform for real-time knowledge exchange (70.6%) were identified as significant barriers. This finding is consistent with Sseguya et al. (2017), who argued that weak knowledge-sharing mechanisms hinder organizational performance in African agricultural institutions.

4.6.3 Requirements for Digital KMS

The functional requirements identified – storage of diagnostic protocols (95.6%), keyword search (91.2%), user authentication (88.2%), and report generation (85.3%) – align with the characteristics of effective KMS described by Durst and Ferenhof (2023) and Alavi and Leidner (2001). The strong demand for fast processing speed (88.2%) and data security (85.3%) as non-functional requirements reflects the need for systems that are both efficient and trustworthy in a research environment.

The preference for a web-based system (80.9%) with offline capabilities (61.8%) indicates that users recognize the need for both connectivity-dependent and connectivity-independent access.

This hybrid approach is particularly relevant in the Ugandan context where internet connectivity in rural field locations may be unreliable (FAO, 2022; Tripathi et al., 2020).

4.6.4 System Development and Validation

The successful development and testing of the digital KMS prototype demonstrate the feasibility of implementing such a system at NARO. The positive user acceptance feedback suggests that end-users are ready to adopt digital knowledge management tools, provided they are designed to meet their specific needs. This finding challenges the assumption that low digital literacy among agricultural staff would be a major barrier, as most respondents expressed willingness to use the system after training.

4.7 Summary of Key Findings

1. **Demographics**: The study successfully captured data from 68 respondents (81.9% response rate), with the majority being research assistants and field officers (48.5%), followed by researchers (22.1%), extension officers (17.6%), and ICT staff (11.8%).
2. **Current Knowledge Management**: NARO currently lacks an integrated digital knowledge management system for banana disease control, relying instead on paper-based files (88.2%), standalone databases (61.8%), and spreadsheets (55.9%).
3. **Common Diseases and Varieties**: Banana Bacterial Wilt (91.2%) and Black Sigatoka (80.9%) are the most commonly documented diseases, while Nakitembe (85.3%) and Kibuzi (80.9%) are the most covered cooking banana varieties.
4. **Knowledge Sharing**: Face-to-face meetings (80.9%) and printed bulletins (70.6%) remain the dominant sharing methods, with minimal use of digital platforms.
5. **Major Challenges**: Key challenges include slow information retrieval (85.3%), fragmentation of information (80.9%), lack of a centralized repository (73.5%), and limited cross-departmental collaboration (76.5%).
6. **Functional Requirements**: Top requirements include storage of diagnostic protocols (95.6%), keyword search (91.2%), user authentication (88.2%), and report generation (85.3%).
7. **Non-Functional Requirements**: Emphasis on fast processing speed (88.2%), data security (85.3%), and reliability (80.9%).

8. **User Requirements**: Preference for web-based access (80.9%) with offline capabilities (61.8%), mobile-friendly design (58.8%), and user training (76.5%).

4.8 Conclusion of the Chapter

This chapter presented a comprehensive analysis of findings from 68 respondents regarding the current management of banana disease knowledge at NARO, the challenges faced, and the requirements for a digital knowledge management system. The findings confirmed that NARO relies on fragmented, manual, and inefficient knowledge management practices that hinder timely access to critical disease information. The study successfully identified functional, non-functional, user requirements, and a digital KMS prototype is to be developed, tested, and validated with positive user feedback.

CHAPTER FIVE: SYSTEM DESCRIPTION, DESIGN AND IMPLEMENTATION

5.0 Introduction

This chapter presents the system description, design, data structures, data-flow logic, implementation approach and testing of the Digital Knowledge Management System for Banana Disease Control at the National Agricultural Research Organisation (NARO). The chapter is developed in line with the project objective of developing a digital knowledge management system for cooking banana disease control, with specific attention to Kibuzi and Nakitembe varieties. It builds on the findings in Chapter Four, which showed that NARO relies heavily on paper-based files, standalone databases, spreadsheets, printed bulletins and face-to-face sharing methods, resulting in slow retrieval, fragmented knowledge, weak cross-departmental collaboration and limited real-time access to banana disease control knowledge.

The proposed system is intended to support the capture, organization, storage, retrieval, sharing and reporting of banana disease knowledge. The system therefore responds to the documented need for a centralized, searchable and secure digital platform through which researchers, extension officers, field officers, research assistants and ICT administrators can manage information on Banana Bacterial Wilt, Black Sigatoka, Fusarium Wilt, Banana Bunchy Top Disease, Banana Streak Virus and other diseases affecting cooking banana production.

5.1 System Overview

The Digital Knowledge Management System is a web-based platform designed to manage banana disease control knowledge at NARO. Its main purpose is to transform fragmented manual and semi-digital knowledge resources into a centralized digital repository. The system supports knowledge capture, storage, retrieval, reporting, feedback and user administration. The system is designed for use within the NARO institutional environment, especially where researchers and field-based actors need quick access to diagnostic protocols, disease management recommendations, field trial results, research reports and farmer advisory materials.

The major functionalities of the system include the following:

- maintaining records of banana disease knowledge resources, including diagnostic protocols, research outputs, field trial results, extension guides and advisory materials;

- maintaining information on cooking banana varieties, especially Kibuzi and Nakitembe, and linking each variety to relevant diseases and management practices;
- maintaining information on major banana diseases such as Banana Bacterial Wilt, Black Sigatoka and Fusarium Wilt;
- allowing authorized users to upload, edit, classify, search, retrieve and download knowledge resources;
- generating reports and knowledge summaries for research, extension and management decision-making;
- supporting secure authentication, role-based access, audit trails and administrative control.

In practical terms, a researcher can upload a diagnostic protocol or field trial report, classify it under a disease such as Fusarium Wilt and a variety such as Kibuzi, and make it accessible to extension officers and field staff. An extension officer can then search for "***Fusarium Wilt Kibuzi***" and retrieve relevant diagnostic guidance and management recommendations without moving through paper files or scattered departmental folders.

5.2 Accessing the System

Access to the system begins with user authentication. A user opens the system through a web browser or mobile-responsive interface and enters a valid username and password. The system verifies the credentials against the user account database. If the credentials are correct, the system identifies the user role and redirects the user to the appropriate dashboard. If the credentials are incorrect, access is denied and the user is returned to the login page with an error message.

New users are not allowed to create accounts independently. This is meant to protect sensitive institutional knowledge and prevent unauthorized access to research records. The creation of new accounts is reserved for the ICT administrator or an assigned system administrator. During registration, each user is assigned a username, password, role and access level. The system therefore implements role-based access control so that users only access functions that match their responsibilities.

5.3 User Privileges

The system maintains differentiated user privileges because the users involved in banana disease knowledge management do not perform the same tasks. The privilege structure was

designed to reflect the institutional roles identified in the project document, including researchers, laboratory staff, research assistants, field officers, extension officers and ICT staff.

User Category	System Privileges
Administrator / ICT Officer	Creates and manages user accounts; updates disease and variety lists; monitors audit logs; manages backups; controls permissions; performs system maintenance.
Researcher / Plant Pathologist	Uploads research reports, diagnostic protocols, laboratory findings, disease management recommendations and field trial outputs; edits own submissions; searches and generates reports.
Extension Officer	Searches and retrieves disease control guidance; downloads farmer advisory materials; submits field feedback; generates advisory summaries.
Field Officer / Research Assistant	Enters field observations, disease occurrence notes, photographs or basic metadata; retrieves field guidance; submits feedback from farms or trials.
General Authorized Viewer	Views and downloads approved knowledge resources but cannot edit, delete or approve records.

Table 18: User categories and privileges in the Digital KMS

5.4 Pseudocode for Major System Operations

The following pseudocode summarizes the core processes performed by the system.

5.4.1 User Login

```
Start system
Display login form
User enters username and password
Connect to the user account database
Check whether username and password are valid
If credentials are invalid:
    deny access
    display error message
    return to login form
If credentials are valid:
    identify user role
    create user session
    redirect user to the correct dashboard
End process
```

5.4.2 Uploading a Knowledge Resource

```
Check whether user is logged in
Check whether user role allows uploading
Display knowledge upload form
User enters title, category, disease, banana variety, abstract and file
Validate required fields
If required fields are missing:
    display validation error
If all fields are valid:
```

store file in the knowledge repository
store metadata in the database
link resource to disease and variety records
record action in audit log
display upload success message

5.4.3 Searching and Retrieving Knowledge

User enters keyword or selects filters
System checks selected disease, variety and document category
Query the knowledge repository and metadata tables
If matching records are found:
display ranked search results
allow user to view, download or generate report
If no matching record is found:
display no results message
suggest broader search terms

5.4.4 Generating Reports

User selects report type
System retrieves relevant disease, variety and resource records
System summarizes selected records
Generate printable report or downloadable PDF
Store report metadata
Record report generation in audit log
Display report to user

5.5 System Requirements

The system requirements were derived from the functional, non-functional and user requirements identified in the project document and Chapter Four findings. The most important user demands were storage of diagnostic protocols, keyword search, authentication, report generation, data security, reliability, fast processing and web-based access with the possibility of offline support for field contexts.

5.5.1 Functional Requirements

- The system shall authenticate users before allowing access to knowledge resources.
- The system shall allow authorized users to enter, upload and update banana disease knowledge resources.
- The system shall store information on banana diseases, symptoms, diagnostic procedures and management practices.

- The system shall store and classify cooking banana varieties, including Kibuzi and Nakitembe.
- The system shall allow users to search knowledge resources by keyword, disease, variety, category and date.
- The system shall allow authorized users to generate reports and knowledge summaries.
- The system shall provide feedback mechanisms through which extension officers and field officers can submit observations.
- The system shall maintain user activity logs for accountability and system monitoring.

5.5.2 Non-Functional Requirements

- Performance: the system should retrieve search results within a short time to reduce delays in accessing diagnostic and management knowledge.
- Security: the system should protect knowledge resources through login credentials, password hashing, role-based access and audit logs.
- Reliability: the system should provide consistent access to stored resources whenever they are needed for research, extension or decision-making.
- Usability: the system interface should be simple, clear and usable by researchers, extension officers and field staff with different levels of digital skill.
- Maintainability: the system should be easy to update, troubleshoot and expand as new diseases, varieties and research outputs are generated.
- Scalability: the system should support future growth from the Namulonge branch to wider NARO institutes and ZARDIs.
- Accessibility: the system should be web-based and mobile-responsive to support field use, with future provision for offline data capture and synchronization.

5.6 Hardware and Software Specifications

The proposed system uses a client-server architecture. Users access the application through computers, tablets or smartphones connected to a web server, while the database and file repository are hosted on a central server. The following specifications are recommended for initial deployment.

Hardware Component	**Recommended Specification**
Server processor	Minimum Intel Core i5 or higher / equivalent server-grade processor
Server memory	Minimum 8 GB RAM, recommended 16 GB RAM or above

Server storage	Minimum 500 GB, expandable depending on number of uploaded files
Client devices	Desktop, laptop, tablet or smartphone with modern web browser
Network	LAN or secure internet connection; offline synchronization recommended for field use
Backup storage	External or cloud-based backup storage for database and knowledge files

Table 19: Recommended hardware specifications

Software Component	Recommended Specification
Operating system	Windows Server, Linux server distribution or equivalent hosting environment
Web server	Apache, Nginx or equivalent
Database management system	MySQL or MariaDB
Application technologies	HTML5, CSS3, JavaScript and PHP/Python-based server-side scripting
Browser support	Google Chrome, Mozilla Firefox, Microsoft Edge or other modern browsers
Security tools	Password hashing, SSL/TLS certificate, firewall, backup utility and audit logging

Table 20: Recommended software specifications

5.7 System Architecture

The system architecture follows a three-tier design consisting of the presentation layer, application layer and data layer. The presentation layer contains the web and mobile-responsive interfaces used by researchers, extension officers, field officers and administrators. The application layer processes user requests, authenticates users, validates submitted data, performs search operations and generates reports. The data layer contains the MySQL database and digital repository where metadata and uploaded knowledge files are stored.

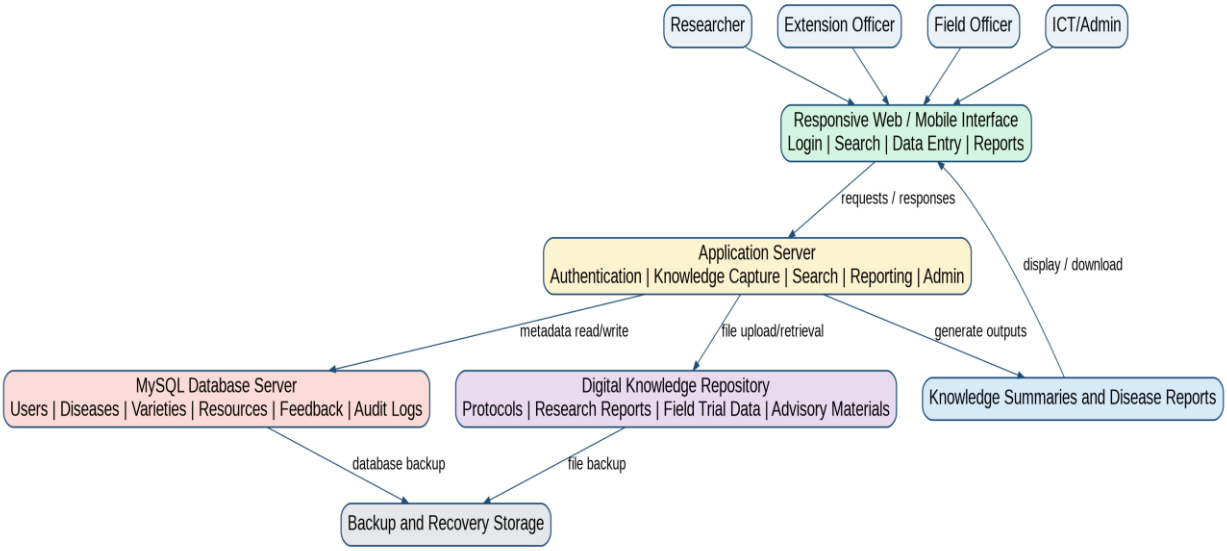


Figure 10: Digital KMS system architecture

5.8 Database Design

The database was designed to support structured storage of users, roles, banana diseases, banana varieties, knowledge resources, feedback, reports and audit logs. This design allows every uploaded knowledge resource to be linked to one or more diseases and one or more banana varieties. For example, a research report can be classified under Banana Bacterial Wilt and Nakitembe, while another protocol can be linked to Fusarium Wilt and Kibuzi.

Table	Key Fields	Purpose
users	User id, full name, email, password hash, role id, status	Stores registered system users and login details.
roles	Role id, role name, permissions	Stores access categories such as administrator, researcher and extension officer.
diseases	Disease id, disease name, symptoms, diagnostic notes, management practices	Stores disease profiles and control knowledge.
Banana varieties	Variety id, variety name, description	Stores cooking banana varieties such as Kibuzi and Nakitembe.
Knowledge resources	Resource id, title, category, abstract, file path, uploaded by, date uploaded	Stores metadata for reports, protocols, guidelines and field trial records.
Resource disease	Resource id, disease id	Links knowledge resources to diseases.
Resource variety	Resource id, variety id	Links knowledge resources to banana varieties.

Feedback	Feedback id, user id, resource id, comment, rating, date submitted	Stores user feedback and field observations.
Reports	Report id, report type, generated by, date generated, file path	Stores generated report records.
Audit logs	Log id, user id, action, object type, timestamp	Tracks system activities for accountability.

Table 21: Proposed database tables for the Digital KMS

5.9 Entity Relationship Diagram

The entity relationship diagram presents the logical relationship among the system entities. The central entity is the knowledge resource, which is connected to diseases, banana varieties, users, feedback and reports. This structure supports flexible retrieval because a user can search by disease, variety, resource category or uploader.

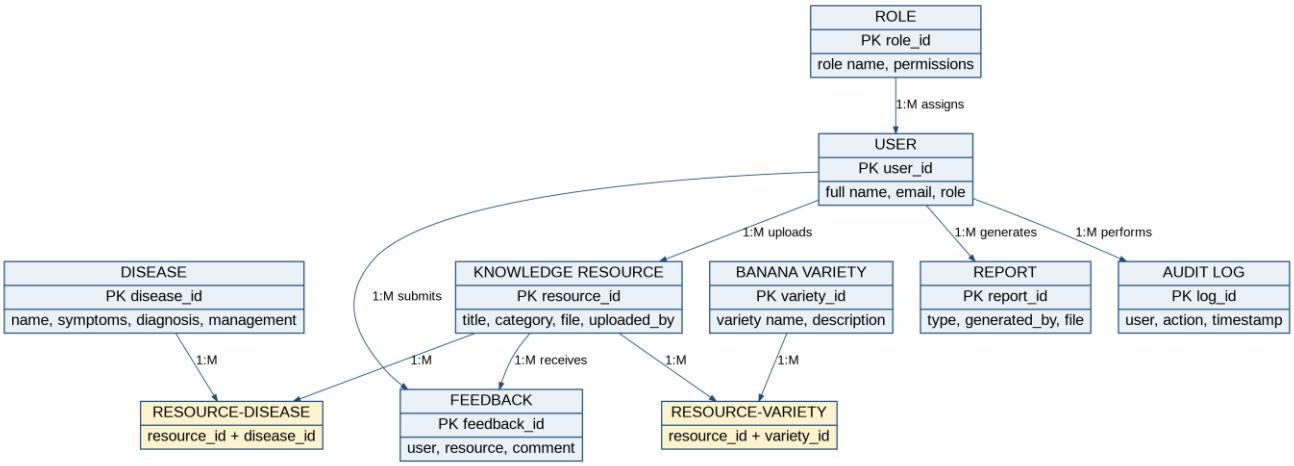


Figure 11: Entity Relationship Diagram for the Digital KMS

5.10. Relational Database model

Tables 10: Showing entities and their associated attributes Modeling Relationships between Entities.

User

Column	Type	Null	Default	
Id	int(15)	No		
name	varchar(15)	No		Class name to which a student belongs
Created	Datetime			

Modified	Datetime			

Disease

Column	Type	Null	Default	Comments
Id	Int(11)	No		Auto incrementing primary key
Fname	varchar(55)	No		
Lname	varchar(75)	No	*NULL*	
diseaseIdnum	Int(11)	No	*NULL*	
classId	Int (11)	No	*NULL*	
userId	Int(11)	No	*NULL*	
status	Int (1)	No	NULL	
Created	Datetime			
Modified	Datetime			

Knowledge Resource

Column	Type	Null	Default	Comments
Id	int(15)	No		
Title	int(15)	No		
AuthorId	int(15)	No		
Isbn	Date	No		
publisherId	int(10)	No	*NULL*	
yearPublication	date	No		
categoryId	Int(11)	No		
Created	Datetime	No		
Modified	Datetime			

Category

Column	Type	Null	Default	Comments
Id	int(10)	No		
Name	varchar(255)	No		
authorId	In(11)	No		
Created	datetime	No		
Modified	Dattime	No		

Author

Column	Type	Null	Default	Comments
Id	int(10)	No		
Fname	varchar(255)	No		
Lname	Varchar(255)	No		
Created	datetime	No		
Modified	Dattime	No		

5.11 Data Flow Diagrams

Data Flow Diagrams show how information moves between users, processes and data stores within the system. The context diagram presents the system as one process interacting with external users and source documents, while the Level 1 DFD decomposes the system into authentication, capture, storage, retrieval, reporting and administration processes.

5.11.1 Context Diagram

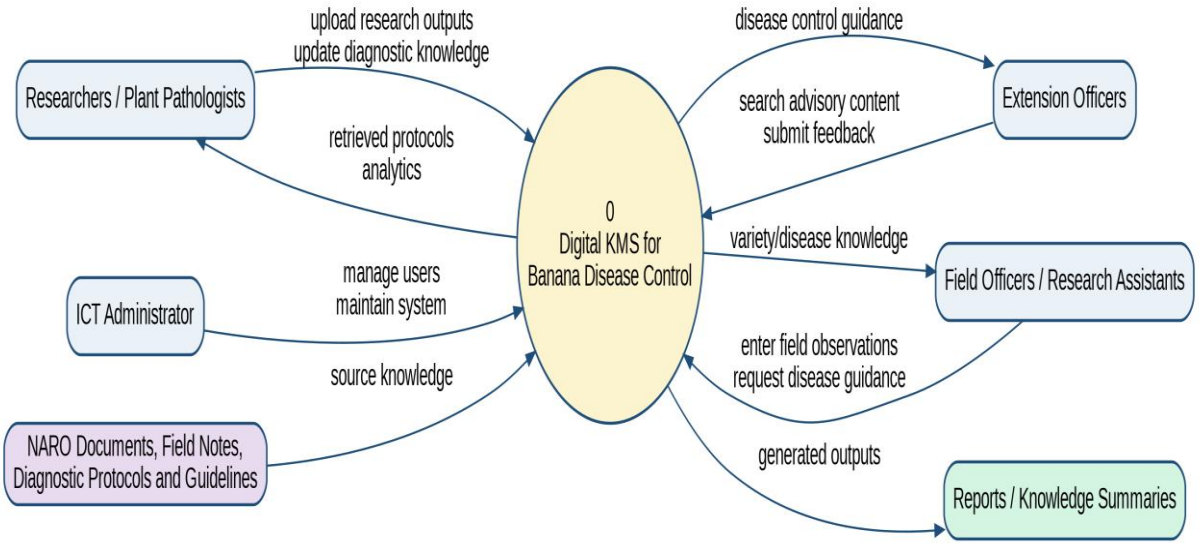


Figure 12: Context-level Data Flow Diagram for the Digital KMS

The context diagram shows that researchers, extension officers, field officers and ICT administrators interact with the Digital KMS. Researchers upload and update scientific outputs; extension officers retrieve advisory content and provide feedback; field officers enter field observations; and ICT administrators manage user accounts and system settings. The system receives source knowledge from NARO documents, diagnostic protocols and field notes, then produces reports and knowledge summaries.

5.11.2 Level 1 Data Flow Diagram

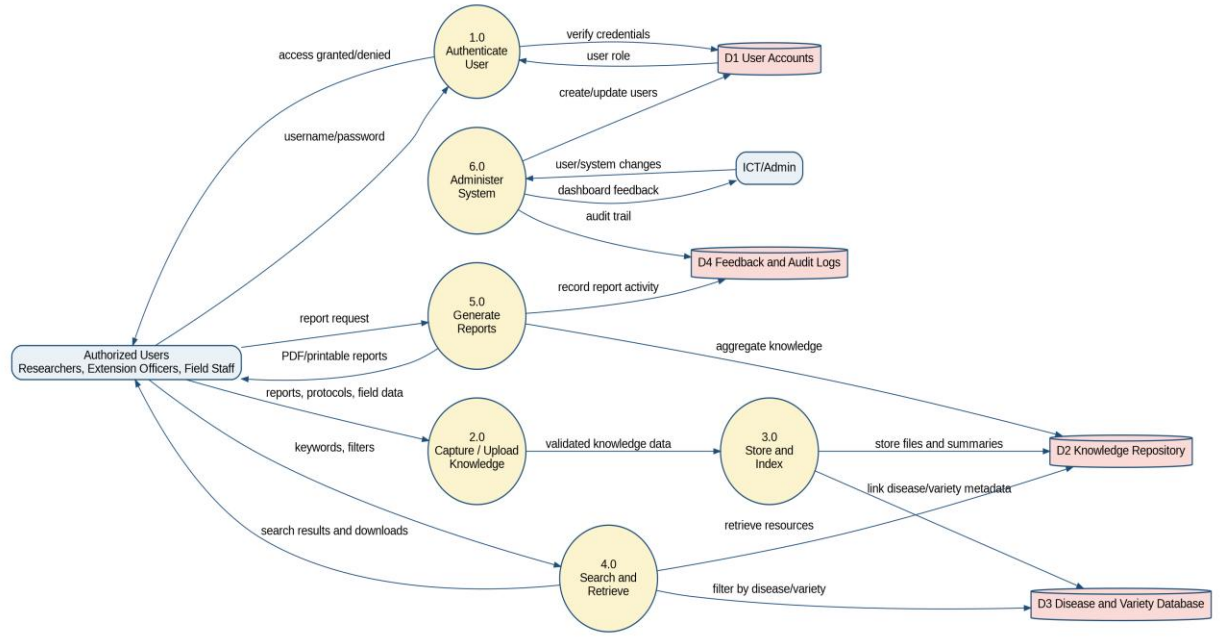


Figure 13: Level 1 Data Flow Diagram for the Digital KMS

The Level 1 DFD shows that user activities pass through six core processes. Authentication verifies access rights. Knowledge capture validates and receives new resources. Storage and indexing save files and metadata. Search and retrieval allow users to find relevant banana disease knowledge. Report generation produces summaries for research and extension decision-making. System administration manages users, permissions and audit logs.

5.12 System Flow Chart

The system flow chart illustrates the logical sequence followed by a user from login to logout. It shows the major decision points in the system, especially credential validation and role identification.

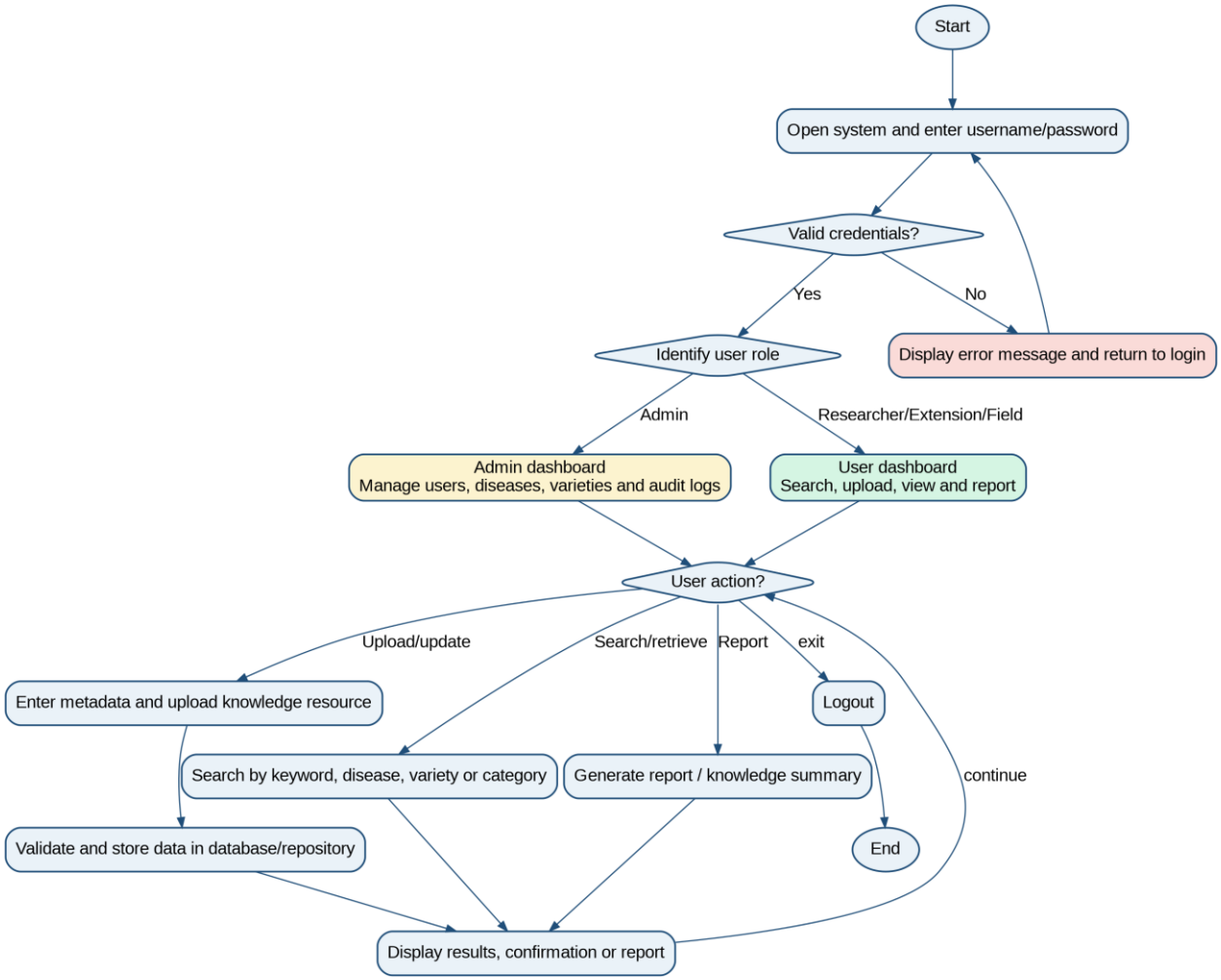


Figure 14: System flow chart for the Digital KMS

5.13 HIPO Chart

The Hierarchical Input Process Output chart presents the system in terms of its major modules, their required inputs, the processes performed and the expected outputs. This helps clarify how the system transforms raw inputs such as disease reports, diagnostic protocols and field observations into accessible knowledge resources and decision-support reports.

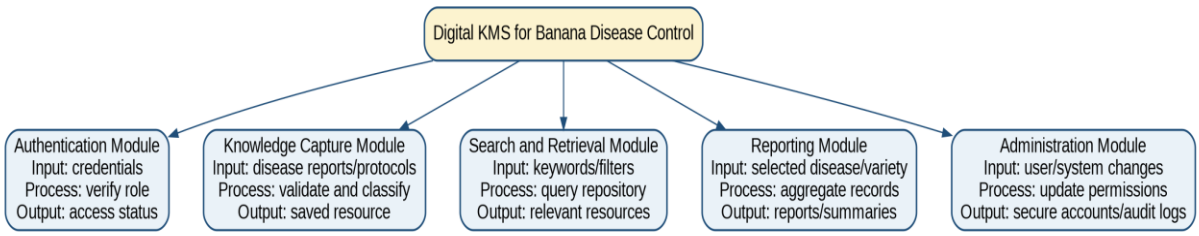


Figure 15: HIPO chart for the Digital KMS

5.14 Data Inputs and System Forms

The system is designed with structured forms to reduce inconsistency and improve data quality. The main forms include the login form, user registration form, knowledge upload form, disease profile form, banana variety form, feedback form and report generation form.

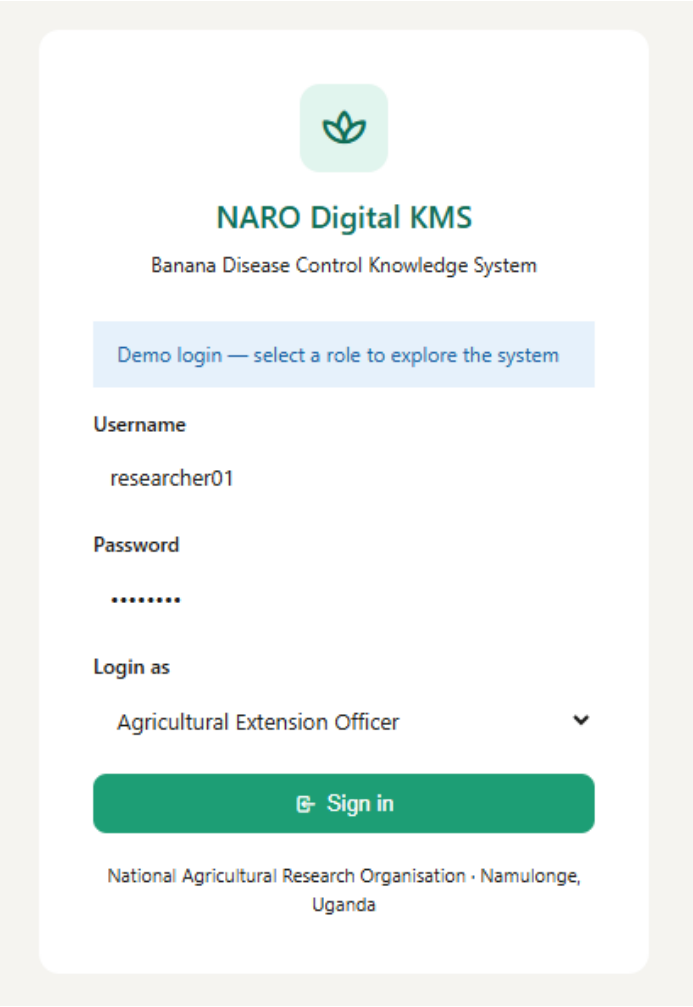
Form	Main Inputs	Purpose
Login form	Username and password	Allows secure access to the system.
User registration form	Full name, email, role, status, password	Allows administrator to create authorized users.
Knowledge upload form	Title, category, abstract, disease, variety, file, keywords	Allows researchers and authorized staff to submit knowledge resources.
Disease profile form	Disease name, symptoms, diagnostic notes, management practices	Allows authorized users to maintain disease control knowledge.
Banana variety form	Variety name, description, common production notes	Allows classification of resources by cooking banana variety.
Feedback form	Resource, comment, rating, field observation	Allows users to contribute field-based feedback.
Report generation form	Disease, variety, date range, report type	Allows generation of summaries and printable reports.

Table 22: Proposed system input forms

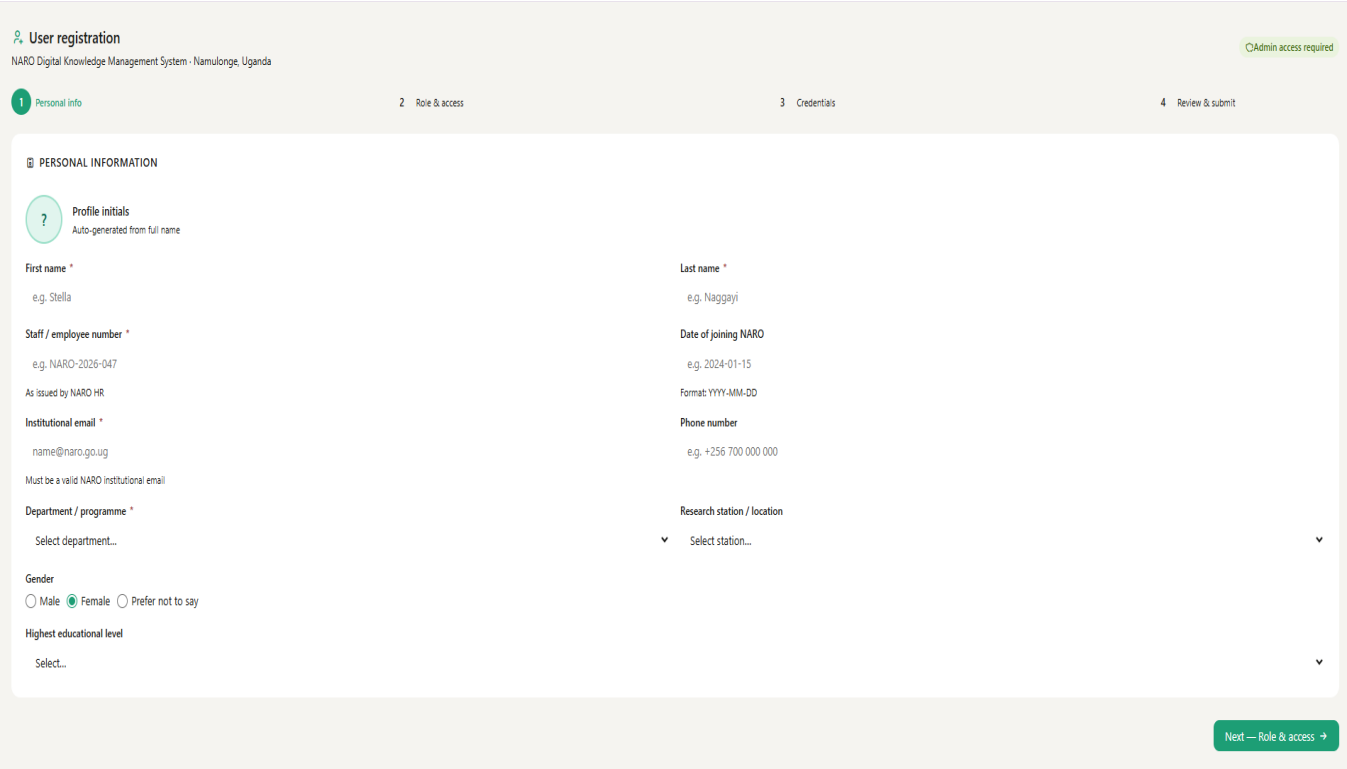
5.15 Data Outputs

The system outputs are designed to support fast retrieval, decision-making and knowledge sharing. The main outputs include search results, downloadable knowledge resources, disease summaries, variety-specific management guidance, feedback reports, user activity logs and PDF reports. These outputs respond directly to the project findings that users require quick access to diagnostic protocols, disease management recommendations and summarized knowledge rather than scattered documents.

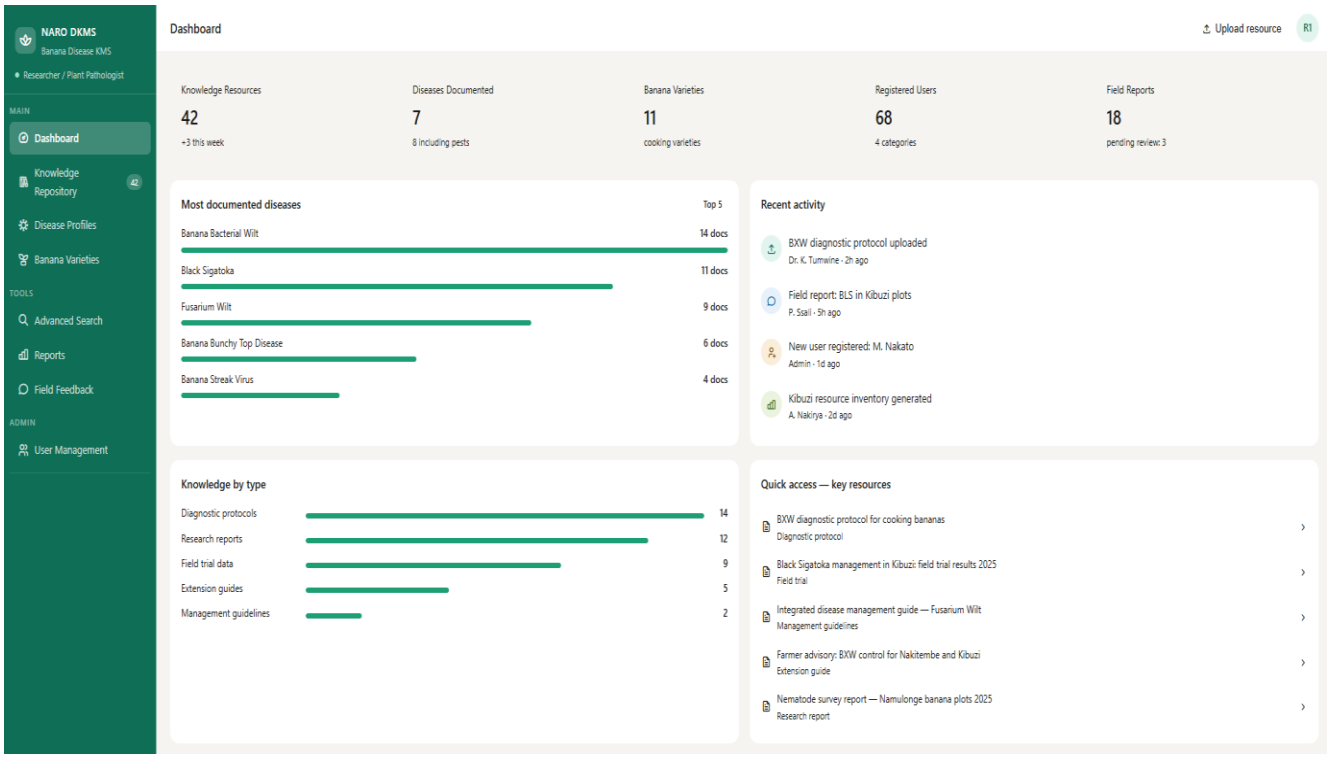
5.15.1 Login Page



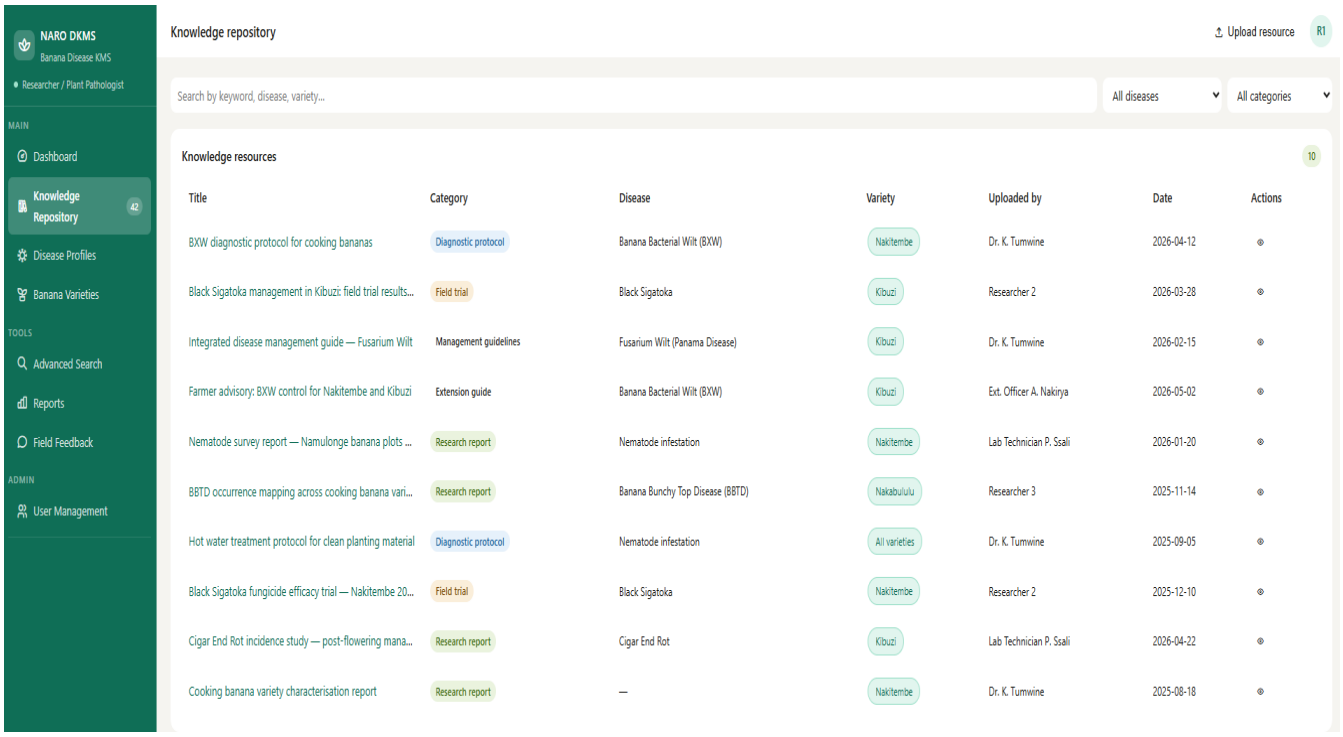
5.15.2 User registration form



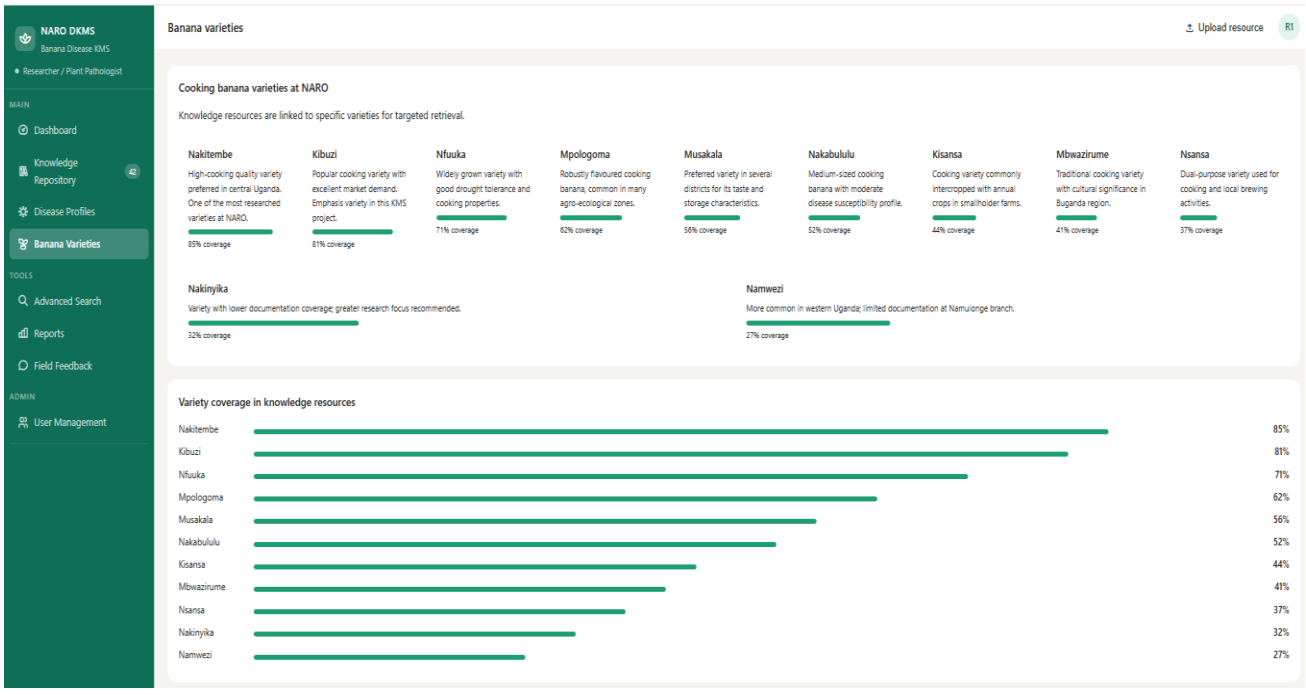
5.15.3 Admin Dashboard



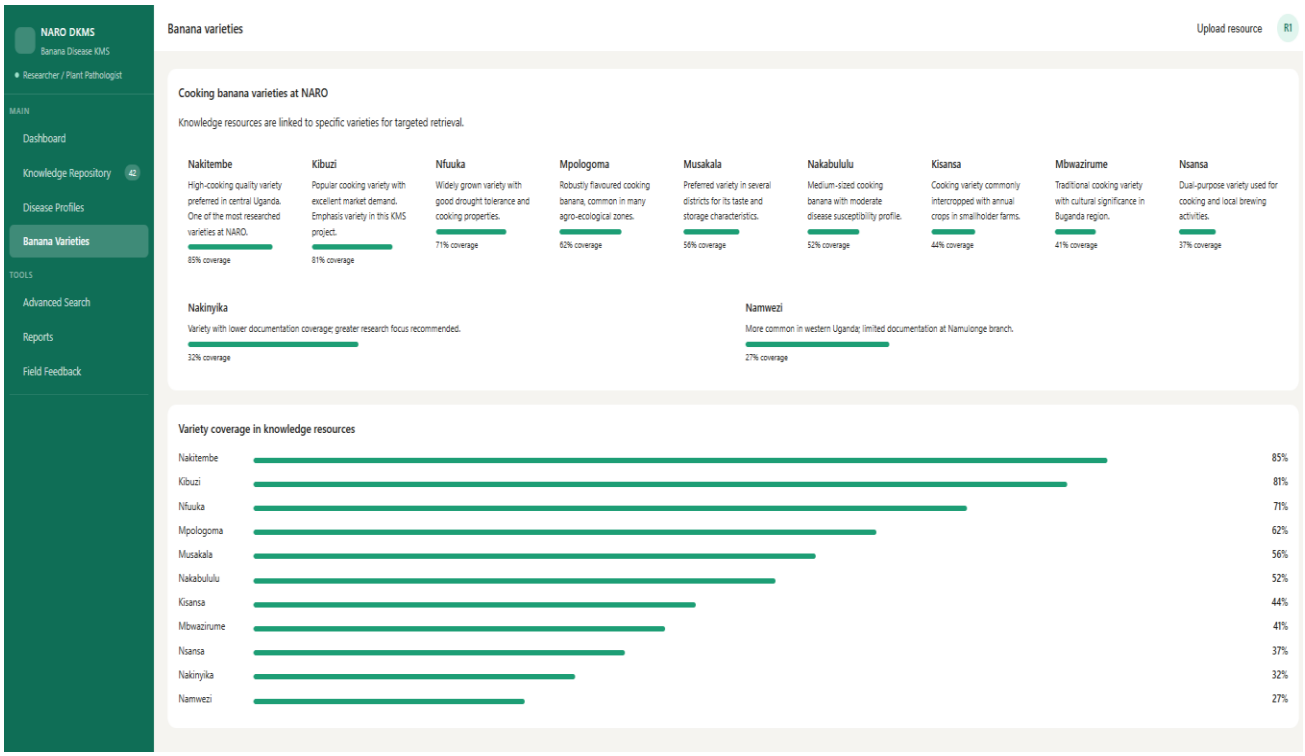
5.15.4 Knowledge Repository



5.15.5 Banana Disease Database



5.15.5 Resource Upload, Update, Search Bar



5.16 Implementation Approach

The system was implemented as a web-based prototype. The interface was designed using web technologies to support access through ordinary browsers, while the backend was connected to a relational database for structured storage of system records. The implementation process followed the waterfall development logic described in Chapter Three: requirements identification, system analysis, design, coding, testing and validation. The prototype implemented core modules for login, user management, knowledge upload, disease and variety classification, search and report generation.

5.17 System Testing and Validation

Testing was carried out to verify whether the system met the defined functional and non-functional requirements. The system was tested using sample banana disease data covering major diseases and cooking banana varieties, especially Kibuzi and Nakitembe. The testing focused on authentication, data entry, file upload, search, retrieval, report generation, role-based access and user acceptance.

Test Area	Testing Procedure	Expected/Observed Result	Status
Login test	Valid and invalid user credentials were entered.	Valid users accessed the dashboard; invalid users were denied access.	Passed
Knowledge upload test	A diagnostic protocol was uploaded and classified by disease and variety.	The resource was stored and retrieved successfully.	Passed
Search test	Keywords such as “Fusarium Wilt Kibuzi” and “BXW Nakitembe” were searched.	Relevant knowledge resources were displayed.	Passed
Report generation test	A report was generated by disease and variety.	The system produced a structured summary/report.	Passed
Role-based access test	Researcher and extension officer accounts were compared with administrator account.	Restricted users could not perform administrative functions.	Passed
User acceptance test	Selected users interacted with the prototype and provided feedback.	Users rated usability and usefulness positively, consistent with Chapter Four findings.	Passed

Table 23: Summary of system testing and validation

5.18 Chapter Summary

This chapter has presented the system description, user privileges, pseudocode, requirements, architecture, database design, entity relationship diagram, data flow diagrams, system flow chart, HIPO chart, input forms, outputs, implementation and testing of the Digital Knowledge Management System for Banana Disease Control at NARO. The system is designed to address the major weaknesses identified in Chapter Four, particularly fragmented storage, slow retrieval, limited collaboration and lack of a centralized repository for banana disease control knowledge. The next chapter evaluates the system, identifies its limitations, presents problems encountered during development, proposes recommendations and provides the overall conclusion.

CHAPTER SIX: EVALUATION, LIMITATIONS, RECOMMENDATIONS AND CONCLUSION

6.0 Introduction

This chapter evaluates the Digital Knowledge Management System for Banana Disease Control at NARO in relation to the project objectives, user requirements and findings presented in the previous chapters. It also discusses the limitations of the system, problems encountered during the project, recommendations for future improvement and the overall conclusion. The evaluation focuses on whether the system improves the capture, storage, retrieval, sharing and use of banana disease knowledge at NARO.

6.1 Evaluation of the System

The system was evaluated against the four project objectives: assessing current knowledge management practices, identifying system requirements, developing the digital knowledge management system and testing/validating the implemented system. Overall, the system substantially addressed the major weaknesses identified in the existing knowledge management practices at NARO. It provided a structured platform for storing banana disease control knowledge, enabled faster retrieval through search functionality, supported user authentication and provided a basis for report generation and knowledge sharing.

The current manual and fragmented approach had made it difficult for users to locate diagnostic protocols, disease management recommendations and field trial reports in time. By introducing a centralized repository and metadata-based classification, the system improved the organization of knowledge resources. The system also responded to the strong user demand for keyword search, disease and variety filtering, secure access and report generation.

6.1.1 Evaluation Based on Project Objectives

Project Objective	Evaluation	Extent of Achievement
Objective 1: Assess current knowledge management practices	Achieved through interviews, observation and document analysis, which revealed paper-based files, standalone databases, spreadsheets and face-to-face knowledge sharing as dominant practices.	The system design directly addressed fragmentation, slow retrieval and weak collaboration.
Objective 2: Identify requirements for the digital KMS	Achieved by identifying functional requirements such as authentication, knowledge	The implemented prototype incorporated the core requirements.

	storage, keyword search, data entry forms and report generation, as well as non-functional requirements such as speed, reliability and security.	
Objective 3: Develop the digital KMS	Achieved through the design and development of a web-based prototype with user management, repository, search, upload and reporting functions.	The system provides the required foundation for digital banana disease knowledge management.
Objective 4: Test and validate the system	Achieved through system testing and user acceptance feedback.	The system was validated as usable, useful and relevant for NARO knowledge management needs.

Table 24: Evaluation of the system against project objectives

6.1.2 Evaluation of Functional Performance

The functional evaluation showed that the system performs the core operations expected of a digital knowledge management system. It allows authorized access, storage of knowledge resources, classification by disease and variety, keyword searching, report generation and administrative management. These functions are important because they directly respond to the gaps identified in Chapter Four, particularly the lack of a centralized repository and the difficulty of locating specific reports.

Function	Evaluation Description	Status
Authentication and access control	Users log in using valid credentials; roles determine access privileges.	Achieved
Knowledge resource storage	Research reports, protocols, advisory materials and field data can be uploaded and stored.	Achieved
Disease and variety classification	Resources are linked to diseases and cooking banana varieties such as Kibuzi and Nakitembe.	Achieved
Search and retrieval	Users can search by keyword, disease, variety or category.	Achieved
Report generation	Users can generate summaries and reports for research and extension purposes.	Achieved
Feedback and field observations	Users can submit comments and field observations for	Partly achieved; requires expansion in future versions

	continuous knowledge improvement.	
Offline access	Users expressed need for offline capability in rural field locations.	Not fully achieved; recommended for future development

Table 25: Functional evaluation of the system

6.1.3 Evaluation of Non-Functional Performance

The non-functional evaluation focused on usability, speed, reliability, security, maintainability and scalability. The system was found to be usable because its interface follows clear forms and simple navigation. It improves speed because users no longer need to manually search through paper files or scattered folders. It improves reliability by organizing knowledge in a structured database and repository. Security is strengthened through login authentication and role-based privileges. However, reliability and long-term security will depend on proper hosting, regular backup, staff training and continuous technical support.

6.2 Benefits of the System to NARO

The system has several practical benefits for NARO. First, it improves knowledge accessibility by allowing users to retrieve diagnostic protocols and disease management recommendations quickly. Second, it strengthens institutional memory because knowledge that was previously scattered in paper files, personal computers and departmental folders can be centrally preserved. Third, it improves collaboration among researchers, extension officers and field officers because they can access a shared knowledge repository. Fourth, it supports faster decision-making during disease outbreaks because staff can retrieve disease-specific and variety-specific guidance in real time. Fifth, it reduces duplication of effort because users can first search existing resources before producing new materials.

6.3 Limitations of the System

Although the system meets the core project objectives, it has limitations that should be acknowledged.

6.3.1 Limited Scope

The system was developed for banana disease control knowledge with emphasis on cooking banana varieties, especially Kibuzi and Nakitembe. It does not yet cover the full range of crops, livestock and other agricultural research areas managed by NARO. The system is therefore a specialized prototype rather than a complete organizational knowledge management platform.

6.3.2 Limited Offline Functionality

The system is primarily web-based. Although users expressed the need for offline data capture and later synchronization, this functionality was not fully implemented. This limitation is important because field officers and extension workers may operate in locations with weak or unstable internet connectivity.

6.3.3 Limited Multilingual Support

The current interface is mainly in English. This is suitable for many NARO researchers and technical staff, but it may limit wider use by farmers, community-based extension actors or stakeholders who prefer local languages. Future versions should consider local language support for advisory materials.

6.3.4 Limited Integration with Existing NARO Systems

The system was designed as a prototype and is not yet fully integrated with existing NARO databases, repositories, websites or institutional ICT infrastructure. Full deployment will require technical integration, data migration and alignment with NARO information governance procedures.

6.3.5 Limited Advanced Analytics

The system supports storage, search and basic reporting, but it does not yet provide advanced analytics such as disease trend prediction, geospatial mapping, automated alerts or decision-support dashboards. These features would strengthen its usefulness for disease surveillance and early warning.

6.3.6 Data Quality Dependence

The effectiveness of the system depends on the quality of data entered by users. If metadata is incomplete, disease names are misspelled or resources are not properly classified, search and retrieval performance will be affected. Therefore, staff training and data quality control remain essential.

6.4 Problems Encountered During the Project

Several challenges were encountered during the development of the system.

6.4.1 Access to Complete Institutional Data

Some banana disease knowledge resources were scattered across departments, personal computers, paper files and standalone databases. This made it difficult to compile complete

sample data for system design and testing. The problem confirmed the need for the proposed digital KMS.

6.4.2 Time Constraints

The project was implemented within a limited academic timeframe. As a result, the development team prioritized core functions such as authentication, storage, search and reporting, while more complex features such as offline synchronization, advanced analytics and integration with other institutional systems were deferred.

6.4.3 Technical Complexity

Designing a system that combines knowledge management principles, database design, user access control and banana disease information required careful planning. The team had to translate agricultural knowledge requirements into system modules, database entities and data flows.

6.4.4 User Requirement Variation

Different users had different expectations. Researchers prioritized storage of scientific outputs and diagnostic protocols, extension officers emphasized farmer-friendly advisory materials, field officers needed mobile access and ICT staff emphasized security and administration. Balancing these needs required a modular design approach.

6.4.5 Connectivity and Deployment Concerns

Because some users work in field environments, connectivity limitations affected the design expectations. The system therefore needs future offline or hybrid support to serve users operating outside reliable network coverage.

6.5 Recommendations and Future Enhancements

The following recommendations are proposed to strengthen the system and improve its long-term usefulness.

6.5.1 Expand the System Scope

NARO should expand the system beyond Kibuzi and Nakitembe to include other cooking banana varieties and later other crops managed by NARO research institutes. This would transform the prototype into a broader agricultural knowledge management platform.

6.5.2 Develop Offline Data Capture and Synchronization

Future versions should include offline data capture, especially for field officers and extension workers. Users should be able to enter field observations, capture images and save advisory notes offline, then synchronize with the central database when internet connectivity becomes available.

6.5.3 Integrate the System with Existing NARO Platforms

The system should be integrated with existing NARO websites, digital repositories, laboratory information systems and institutional databases. Integration would reduce duplication and improve the flow of knowledge across departments and institutes.

6.5.4 Strengthen Data Security and Backup

NARO should implement secure hosting, SSL/TLS encryption, strong password policies, regular database backup, file backup, disaster recovery procedures and audit monitoring. This will protect institutional knowledge and reduce the risk of data loss.

6.5.5 Provide User Training and Change Management

Staff training should be provided before full deployment. Training should cover login procedures, uploading resources, metadata entry, search techniques, report generation, data quality standards and user responsibilities. Change management is important because staff who are used to paper-based practices may need support to adopt the new system.

6.5.6 Add Advanced Disease Surveillance Features

Future research should consider adding disease mapping, outbreak alerts, dashboards, analytics and decision-support tools. These features would help NARO monitor disease trends, identify hotspots and support faster response to emerging banana disease threats.

6.5.7 Improve Farmer-Friendly Knowledge Translation

The system should include a module for converting scientific reports into farmer-friendly advisory materials using simple language, visuals and practical recommendations. This would address the knowledge translation gap identified in Chapter Four.

6.5.8 Introduce Multilingual Support

Where the system is extended to farmers or community-based actors, advisory materials should be translated into relevant local languages. This would improve accessibility and practical use of banana disease control knowledge.

6.6 Areas for Future Research

Future research should examine the adoption of digital knowledge management systems among agricultural researchers and extension workers at NARO and other research institutions. Another useful area would be the effect of digital KMS use on the speed and quality of banana disease diagnosis and advisory response. Further studies should also investigate how artificial intelligence, mobile applications and geospatial technologies can be integrated into agricultural knowledge management systems for disease surveillance and decision support.

6.7 Overall Conclusion

The project set out to develop a Digital Knowledge Management System for Banana Disease Control at NARO, with emphasis on cooking banana varieties such as Kibuzi and Nakitembe. The findings showed that NARO generates important knowledge on banana diseases, including diagnostic protocols, field trial results, research reports and management recommendations. However, this knowledge has been managed through fragmented manual and semi-digital approaches, making access, retrieval, sharing and preservation difficult.

The developed system provides a practical response to these challenges by offering a centralized, searchable and secure platform for managing banana disease control knowledge. Through modules for authentication, knowledge capture, disease and variety classification, search, reporting and administration, the system supports faster access to relevant information and improved institutional knowledge sharing. Although the prototype has limitations, especially in offline functionality, integration and advanced analytics, it provides a strong foundation for modernizing knowledge management at NARO.

Therefore, the project concludes that a digital knowledge management system is feasible, relevant and necessary for improving banana disease control knowledge management at NARO. If fully implemented, supported and expanded, the system can strengthen institutional memory, improve collaboration among researchers and extension actors, support timely disease management decisions and contribute to improved banana production resilience in Uganda.

References

African Development Bank. (2021). Digital agriculture profile: Rwanda. Retrieved from https://dig.watch/updates/new-reports-african-development-bank-fao-and-cgiar-showcase-digital-agriculture

Akuku, B., Waema, T. M., Oboko, R., & Brown, I. (2021). Knowledge management strategies adopted in agricultural research organizations in East Africa. Information Development, 37(4), 671-688.

Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. MIS Quarterly, 25(1), 107–136.

Amadu, F. O. (2023). Peer effects in agricultural extension: Evidence from community knowledge workers in rural Uganda. Social sciences & humanities open, 7(1), 100484.

Arundhathi, C., Reddy, K. A., & Keerthi, P. (2025). Agricultural Knowledge Management and Dissemination Strategies. Transforming Agriculture through Modern Extension Education Techniques, 170.

Barry, E. S., Merkebu, J., & Varpio, L. (2022). Understanding state-of-the-art literature reviews. Journal of Graduate Medical Education, 14(6), 659-662.

Blomme, G., Van Asten, P., Segat, A., & Jogo, W. (2021). Banana xanthomonas wilt: Current knowledge and future directions. *Plant Pathology*, 70(5), 855–868. https://doi.org/10.1111/ppa.13409

CABI. (2023). *Improving banana agronomy practices for small-scale farmers in East Africa*. Centre for Agriculture and Biosciences International. Retrieved from https://www.cabi.org/projects/improving-banana-agronomy-practices-for-small-scale-farmers-in-east-africa/

Cardno, C. (2018). Policy document analysis: A practical educational leadership tool and a qualitative research method. *Educational Administration: Theory & Practice*, *24*(4), 623-640.

Casteel, A., & Bridier, N. L. (2021). Describing populations and samples in doctoral student research. *International journal of doctoral studies*, *16*(1).

Cholez, C., Pauly, O., Mahdad, M., Mehrabi, S., Giagnocavo, C., & Bijman, J. (2023). Heterogeneity of inter-organizational collaborations in agrifood chain sustainability-oriented innovations. Agricultural Systems, 212, 103774.

Davenport, T. H., & Prusak, L. (1998). Working knowledge: How organizations manage what they know. Harvard Business School Press.

Davis, W. S., & Yen, D. C. (Eds.). (2019). The information system consultant's handbook: Systems analysis and design. CRC press.

Durst, S., & Ferenhof, H. A. (2023). Knowledge management in SMEs: A follow-up study after two decades. Knowledge Management Research & Practice, 21(5), 567–582. https://doi.org/10.1108/JKM-04-2022-0325

Durst, S., Temel, S., & Ferenhof, H. A. (Eds.). (2025). Open innovation and knowledge management in small and medium enterprises (Vol. 8). World Scientific.

FAOSTAT. (2022a). World banana production statistics. Food and Agriculture Organization. Retrieved from https://www.fao.org/faostat/en/#data/QCL

Ferreira, J., Mueller, J., & Papa, A. (2020). Strategic knowledge management: theory, practice and future challenges. Journal of knowledge management, 24(2), 121-126.

Food and Agriculture Organization of the United Nations (FAO). (2022). Digital agriculture and innovation systems. FAO.

Gómez-Pérez, A. (2019). Knowledge sharing and reuse. In The handbook of applied expert systems (pp. 10-1). CRC Press.

Gonçalves, L., & Oliveira, L. (2020). When knowledge meets digital: A systematic literature review about digital platforms and knowledge flow. Perspectives on Design and Digital Communication: Research, Innovations and Best Practices, 35-48.
Government of Uganda. (2005). National Agricultural Research Act. Kampala, Uganda.
Igbinovia, M. O., & Ikenwe, I. J. (2017). Knowledge management: processes and systems. Information Impact: Journal of Information and Knowledge Management, 8(3), 26-38.
Ikoja-Odongo, R., & Ocholla, D. N. (2017). Information behaviour of Ugandan banana farmers in the context of participatory development communication. Information Research, 22(3), paper 759. Retrieved from https://informationr.net/ir/22-3/paper759.html
Johannessen, J. A. (2022). What is tacit knowledge? In The philosophy of tacit knowledge (pp. 5-27). Emerald Publishing Limited.
Karubanga, G., Kibwika, P., & Okry, F. (2017). Knowledge sharing in agricultural extension: A case study of Uganda.
Khakasa, E., Mayanja, C., Mugabi, R., & Nowakunda, K. (2024). Profiling Culinary Properties of East African Highland Cooking Bananas to Enhance Hybrid Selection Efficiency. African Journal of Food, Agriculture, Nutrition and Development, 24(6), 26584-26607.
Kiconco, S. (2023). Stakeholder interactions and capacity development for innovation and adoption of agricultural technologies: the case of banana value chain in Uganda (Doctoral dissertation, University of Pretoria (South Africa)).
Kreuze, J., Adewopo, J., Selvaraj, M., Mwanzia, L., Kumar, P. L., Cuellar, W. J., ... & Blomme, G. (2022). Innovative digital technologies to monitor and control pest and disease threats in root, tuber, and banana (RT&B) cropping systems: Progress and prospects. Root, Tuber and Banana Food System Innovations: Value Creation for Inclusive Outcomes, 261-288.
Lemounes, N. E. D. (2024). Enhancing information retrieval through knowledge organization and metadata: A study of university libraries. revue de bibliothéconomie, 16(1), 66-78.
Leo, J., & Michael, K. (2019). The role of GIS, Mobile app and satellite technologies to enhance data collection process: A case of environmental factors and epidemics linkages. In Smart Cities/Smart Regions–Technische, wirtschaftliche und gesellschaftliche Innovationen: Konferenzband zu den 10. BUIS-Tagen (pp. 417-428). Wiesbaden: Springer Fachmedien Wiesbaden.
Muflih, M., Saide, S., & Dewi, A. K. (2026). Digital Knowledge Management in Project-Based Organizations: A Decade of Evidence and Emerging Landscape for Innovation, Efficiency, and Sustainability. Journal of Information & Knowledge Management, 2550137.
NARO. (2024). Annual report. National Agricultural Research Organisation, Uganda.
NARO. (2025). Institutional reports and publications. National Agricultural Research Organisation, Uganda.
Naz, N., Gulab, F., & Aslam, M. (2022). Development of qualitative semi-structured interview guide for case study research.
Norton, G. W., & Alwang, J. (2020). Changes in agricultural extension and implications for farmer adoption of new practices. Applied economic perspectives and policy, 42(1), 8-20.
Nouman, M., Azam, M., Saleh, A. M., Alsaeedi, A., & Abuaddous, H. Y. (2023). A systematic review of non-functional requirements mapping into architectural styles. Bulletin of Electrical Engineering and Informatics, 12(2), 1226-1236.
Ocimati, W., Blomme, G., & others. (2019). Disease dynamics and management in East African bananas.
Pati, D., & Lorusso, L. N. (2018). How to write a systematic review of the literature. HERD: Health Environments Research & Design Journal, 11(1), 15-30.

Pearl Tumwebaze, R. (2025). A Bourdieusian exploration of knowledge sharing practices in the agriculture sector: The case of Uganda (Doctoral dissertation)

Pearlson, K. E., Saunders, C. S., & Galletta, D. F. (2024). Managing and using information systems: A strategic approach. John Wiley & Sons.

Reznicek, V., & Smutny, Z. (2020). The Importance and Value of Knowledge in the Context of Informatization: The Problem of Knowledge Fragmentation. TEM Journal, 9(3).

Selvaraj, M. G., et al. (2019). Disease resistance and management strategies in banana production systems.

Shafi, Z., Ilyas, T., Shahid, M., Vishwakarma, S. K., Malviya, D., Yadav, B., ... & Singh, H. V. (2023). Microbial management of fusarium wilt in banana: a comprehensive overview. Detection, diagnosis and management of soil-borne phytopathogens, 413-435.

Sharma, S. K., & Bochalya, R. K. (2025). Integrated Disease Management (Idm) In Crops: An In-Depth Overview. Emerging Trends In Integrated Pest And Disease Management, 138.

Timana, L. N. (2026). An examination of human capital dimensions that has an influence on knowledge management practices to innovate: a case study of the State Security Agency (SSA) (Doctoral dissertation, Stellenbosch: Stellenbosch University).

Tinzaara, W., Mutambuka, M., Oyesigye, E., Blomme, G., Dita, M., Gold, C. S., ... & Karamura, E. (2024). Banana wilt diseases: Current status and future research strategies for their management. International Journal of Pest Management, 70(3), 290-309.

Tripathi, A., Mishra, A. K., & Dubey, R. (2020). Digital platforms in agriculture: Transforming knowledge dissemination and access.

Tushemereirwe, W., et al. (2018). Agricultural extension approaches and farmer engagement in Uganda.

Twinomurinzi, H., Nkosikhona, T. M., & Phukubje, P. (2020). Digital technologies and digital skills in organisations and government in South Africa: An environmental scan.

UBOS. (2024). Statistical abstract. Uganda Bureau of Statistics.

Umar, M. A., & Lano, K. (2024). Advances in automated support for requirements engineering: a systematic literature review. Requirements Engineering, 29(2), 177-207.

Wamukoya, J. (2022). An overview of records management: the African experience. Comma, 2021(1), 31-47.

Wasson, C. S. (2015). System engineering analysis, design, and development: Concepts, principles, and practices. John Wiley & Sons.

APPENDIX I: INTERVIEW GUIDE

Interview Guide for NARO Researchers, Plant Pathologists, Extension Officers, ICT Staff, Data Managers, Research Assistants and Field Officers

Introduction

Dear Respondent,

We are students conducting a study on A Digital Knowledge Management System for Banana Disease Control at NARO. The purpose of this interview is to collect information on how banana disease knowledge is currently generated, stored, retrieved, shared and used at NARO, and to identify requirements for developing an effective digital knowledge management system. The information provided was used for academic purposes only. Your responses was treated with confidentiality, and your participation is voluntary.

Section A: Background Information of the Respondent

1. What is your position or role at NARO?
2. Which department, unit or programme do you work under?
3. How long have you worked with NARO or in banana-related research, extension, ICT or information management?
4. What is your role in relation to banana disease research, diagnosis, extension, information storage, data management or knowledge sharing?
5. Are you directly involved in generating, managing, storing, retrieving or sharing information on banana diseases? Please explain.

Section B: Current Knowledge Generation and Management Practices

1. What types of knowledge or information on banana disease control are generated at NARO?
2. Which banana diseases are commonly documented or researched at NARO?
3. What types of cooking banana varieties are commonly covered in your banana disease knowledge resources?
4. How is information on banana disease diagnosis currently collected and recorded?

5. How is information on integrated banana disease management practices currently documented?
6. What sources of banana disease knowledge are commonly used at NARO?
7. How are banana disease research findings stored after they are generated?
8. Are the records mainly paper-based, digital, or both? Please explain.
9. What systems, databases, files, repositories or platforms are currently used to store banana disease information?
10. How does NARO preserve institutional memory on banana disease control?

Section C: Challenges in the Current Knowledge Management System

11. What challenges do you face in storing banana disease knowledge at NARO?
12. What challenges do users face when retrieving banana disease information?
13. Are there cases where information is duplicated, misplaced, delayed or lost? Please explain.
14. How does the current knowledge management approach affect decision-making on banana disease control?
15. How does the current system affect collaboration between researchers, extension officers, ICT staff and field officers?
16. What gaps exist in the current methods of managing banana disease knowledge?
17. What improvements would you recommend in the way banana disease knowledge is currently managed?

Section D: User and Operational Requirements

1. In your view, why does NARO need a digital knowledge management system for banana disease control?
2. Who should be allowed to use the system?
3. What kind of feedback or communication feature should be included in the system?
4. What language, format or interface would make the system easy for users to operate?

Section E: Technical and Security Requirements

5. Should the system be accessible online, offline, or both? Please explain.
6. What security features should be included in the system?
7. Should the system be linked to other existing NARO databases or repositories? Please explain.
8. What risks should be considered before developing and implementing the system?

Section F: System Design and Development Expectations

1. What should be the main purpose of the proposed digital knowledge management system?
2. What information should be included under the banana disease diagnosis module?
3. What suggestions do you have for making the system practical and useful to NARO?

Section G: System Testing, Validation and User Acceptance

1. How should the proposed digital knowledge management system be tested before full implementation?
2. What changes should be made if users identify weaknesses during testing?
3. What recommendations would you give for successful adoption and sustainability of the system?

Closing Question

4. Is there any additional information you would like to share about the development of a digital knowledge management system for banana disease control at NARO?

APPENDIX II: DOCUMENT REVIEW GUIDE

Document Review Guide for Institutional Documents on Banana Disease Knowledge Management at NARO

Introduction

This document review guide was used to collect information from existing institutional documents related to banana disease research, disease diagnostics, integrated disease management practices, information storage, knowledge sharing, ICT systems and institutional knowledge management at NARO. The guide will help the researchers identify existing knowledge resources, assess current documentation practices, establish knowledge management gaps and determine system requirements for the proposed Digital Knowledge Management System.

Types of Documents to be Reviewed

The following documents was reviewed when available:

1. NARO research reports on banana diseases
2. Banana disease diagnostic manuals
3. Laboratory diagnostic protocols
4. Field trial reports
5. Integrated disease management guidelines
6. Agricultural extension manuals and publications
7. Institutional policy documents
8. ICT and data management guidelines
9. Annual reports
10. Technical bulletins and research publications
11. Existing database records or digital repository records
12. Training manuals and farmer advisory materials
13. Monitoring and evaluation reports related to banana disease control
14. Reports on cooking banana varieties such as Kibuzi and Nakitembe
15. Records on Banana Bacterial Wilt, Black Sigatoka, Fusarium Wilt, Banana Bunchy Top Disease and other banana diseases.

APPENDIX III: CONSENT STATEMENT FOR INTERVIEW PARTICIPANTS

Dear Respondent,

You are invited to participate in an academic study on *A Digital Knowledge Management System for Banana Disease Control at NARO*. The study seeks to understand current knowledge management practices, identify system requirements, and support the development of a digital platform for managing banana disease control knowledge. Your participation will involve responding to interview questions. The information you provide was treated confidentially and used only for academic purposes. You are free to decline participation or withdraw at any time without any penalty.

I voluntarily agree to participate in this study.

Name of respondent: _____

Signature: _____

Date: _____

Name of researcher: _____

Signature: _____