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Article

Designing and Evaluating a Collaborative Knowledge Management Framework for Leaf Disease Detection

Komal Bashir[1,*], Mariam Rehman[2], Afnan Bashir[3] and Faria Kanwal[1]

[1]Department of Computer Science, Lahore College for Women University, Lahore, 54000, Pakistan
[2]Department of Information Technology, Government College, Faisalabad, 54000, Pakistan
[3]Engage Research Lab, School of Law and Society, University of the Sunshine Coast, Sippy Downs, QLD 4556, Australia
*Corresponding Author: Komal Bashir. Email: komal.bashir@lcwu.edu.pk
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Abstract: Knowledge Management (KM) has become a dynamic concept for inquiry in research. The management of knowledge from multiple sources requires a systematic approach that can facilitate capturing all important aspects related to a particular discipline, several KM frameworks have been designed to serve this purpose. This research aims to propose a Collaborative Knowledge Management (CKM) Framework that bridges gaps and overcomes weaknesses in existing frameworks. The paper also validates the framework by evaluating its effectiveness for the agriculture sector of Pakistan. A software LCWU aKMS was developed which serves as a practical implementation of the concepts behind the proposed CKMF framework. LCWU aKMS served as an effective system for rice leaf disease detection and identification. It aimed to enhance CKM through knowledge sharing, lessons learned, feedback on problem resolutions, help from co-workers, collaboration, and helping communities. Data were collected from 300 rice crop farmers by questionnaires based on hypotheses. Jennex Olfman model was used to estimate the effectiveness of CKMF. Various tests were performed including frequency measures of variables, Cronbach's alpha reliability, and Pearson's correlation. The research provided a KMS depicting KM and collaborative features. The disease detection module was evaluated using the precision and recall method and found to be 94.16% accurate. The system could replace the work of extension agents, making it a cost and time-effective initiative for farmer betterment.

Keywords: Collaborative knowledge management; framework; jennex olfman km success model; knowledge management; rice disease detection

1 Introduction

Knowledge Management (KM) is a multidisciplinary area that involves individuals, knowledge communities, and organizations in the creation and management of knowledge of a particular discipline [1]. Advancements in technology and competitiveness in global economies have made the creation and diffusion of knowledge a critical component to consider while developing work practices [2]. Therefore, in today's world knowledge could be considered as a commodity to design and develop new solutions, address existing problems, and bring innovation in existing processes. The transformation of knowledge involves various sources including individuals, relevant communities, research organizations, and companies responsible for production. The management of knowledge from multiple sources requires a systematic approach that can facilitate capturing all important aspects related to a particular discipline [3–5]. In this regard, researchers have already made advancements in creating KM frameworks that are facilitating various disciplines in improving their work practices, refining their products and services, and contributing to the economy in more effective and efficient manners [6–9].

Knowledge alone cannot assure the success of an organization; it is necessary to manage and share the knowledge [10]. The growth or even survival of any company depends on how efficiently it copes with the knowledge and information residing both inside and outside the organization [11]. Knowledge is generally considered as the most imperative component of competitive advantage for an economy [12,13]. Automating knowledge so that it can be shared with others is an important task [14]. Knowledge sharing is a process of knowledge exchange between individuals to create collective knowledge [15] is considered a key action in the process of KM. Through knowledge sharing, individuals can add their knowledge to knowledge repositories, enrich it with ideas, and ultimately add a competitive advantage for organizational growth [16]. Researchers have concluded that using a knowledge sharing strategy at multiple levels in an organization results reduction in production costs, speedy achievement of goals, enhanced team efficiency, an increase in revenue, and an increase in organizational growth [16–18]. Created and stored knowledge must be shared and disseminated to attain its maximum benefit [19].

Adding a communicative nature to KM gives a flavour of Collaborative Knowledge Management (CKM). Both tacit and explicit information can be shared collaboratively [20,21]. Modern business practices are collaborative in nature; the interaction between partners may be aimed at production or development, or it may simply be targeted at sharing resources or support services [22,23]. Organizations that adopt collaborative technologies must ensure compatibility between different systems and their priorities [21], and managers must find ways to manage collective intellectual knowledge assets [24]. KM is considered an important process for organizations and should be given prime consideration [18].

A KM framework is a system involving people, processes, and technology, as well as controls for effective KM implementation and execution [25]. It is responsible for the smooth flow of knowledge and the identification of gaps and interconnections among different elements [26]. The challenge for knowledge-based domains is to find an approach for the management and support of benefits based on the sharing of information in existing unmanaged activities in collaborative environments.

The focus of this research work is to develop a general framework termed CKMF (Collaborative Knowledge Management Framework) that minimizes the gaps identified in the existing KM frameworks. The primary goal is to facilitate collaboration among users as well as implement the framework using crop disease detection as a case study.

The rest of the paper is structured as follows: In Section 2, existing KM frameworks and their limitations are briefly discussed. In Section 3 materials and methods adopted for developing the framework are stated along with the discussion of the case study (used for the validation of the proposed concept) and hypotheses. In Section 4, the proposed framework is discussed and Section 5 holds results. Section 6 presents the discussion on results and finally, Section 7 provides the conclusion of this research.

2 Related Work

A large amount of research has been conducted on developing KM systems to automate the KM and sharing processes. A number of frameworks have been designed by researchers to automate the KM concept, using processes and technologies that support knowledge asset management [27]. These frameworks are similar in many aspects, but they also consist of unique features and limitations [28]. Limitations in the frameworks lead towards need of improved framework. Tab. 1 presents the summarized view highlighting various features of studied KM frameworks.

Table 1: Summary of the studied KM frameworks

KM framework	Critical success factors	Generic	Domain specific	Technology infra-structure	Multi-level KM	Knowledge transfer	Software features	Collaborative features
[29]	Not addressed	Addressed	Not addressed	Not addressed	Not addressed	Addressed	Partially addressed	Not addressed
[30]	Not addressed	Addressed	Addressed	Addressed	Partially addressed	Addressed	Partially addressed	Addressed
[31]	Addressed	Addressed	Partially addressed	Not addressed	Partially addressed	Partially addressed	Partially addressed	Not addressed
[32]	Not addressed	Addressed	Not addressed	Partially addressed	Partially addressed	Addressed	Partially addressed	Partially addressed
[33]	Not addressed	Addressed	Not addressed	Partially addressed	Partially addressed	Addressed	Addressed	Addressed
[34]	Not addressed	Partially addressed	Addressed	Partially addressed	Partially addressed	Partially addressed	Partially addressed	Partially addressed
[35]	Not addressed	Addressed	Not addressed	Partially addressed	Partially addressed	Addressed	Partially addressed	Not addressed
[36]	Not addressed	Partially addressed	Addressed	Partially addressed	Partially addressed	Partially addressed	Partially addressed	Not addressed
[37]	Partially addressed	Addressed	Addressed	Partially addressed	Addressed	Addressed	Partially addressed	Not addressed
[38]	Not addressed	Addressed	Not addressed	Partially addressed	Partially addressed	Partially addressed	Partially addressed	Partially addressed
[39]	Not addressed	Addressed	Not addressed	Partially addressed	Addressed	Partially addressed	Partially addressed	Not addressed
[40]	Not addressed	Addressed	Not addressed	Not addressed	Partially addressed	Partially addressed	Partially addressed	Not addressed
[41]	Not addressed	Addressed	Not addressed	Partially addressed	Partially addressed	Partially addressed	Partially addressed	Not addressed
[24]	Not addressed	Addressed	Not addressed	Addressed	Partially addressed	Addressed	Partially addressed	Partially addressed
[42]	Partially addressed	Not addressed	Addressed	Not addressed	Addressed	Partially addressed	Not addressed	Not addressed
[43]	Not addressed	Partially addressed	Addressed	Addressed	Addressed	Addressed	Partially addressed	Partially addressed
[44]	Addressed	Not addressed	Addressed	Not addressed	Partially addressed	Partially addressed	Not addressed	Not addressed
[45]	Addressed	Addressed	Addressed	Not addressed	Partially addressed	Not addressed	Not addressed	Not addressed

Note: Addressed ■ Partially addressed ■ Not addressed ■

The importance of KM becomes more significant in sectors where new tasks and projects are quite similar to the previous ones. In such cases, the lessons learned from past experiences are utilized to augment efficiency and effectiveness in future projects. It can significantly benefit the members of a community, as reusing the organizational knowledge can suggestively reduce both time and error, increasing the overall quality of the work that gives rise to the need for a collaborative system [21].

Considering the repetitive nature of agricultural activities and the significance of past trends and experiences for future farming decisions [29], CKMF (proposed in this research) is deployed in the agriculture sector of Pakistan as a case study to measure its effectiveness. Another important feature of the agriculture sector of Pakistan that necessitates KM infrastructure is lack of documentation, low literacy, and outdated extension agent network. A KM software, LCWU aKMS, was developed based on customized CKMF to cater needs of the farming community of Pakistan. A well-structured questionnaire instrument was used to collect feedback from rice crop farmers about the developed system. A sample of 300 rice growers was randomly selected to collect the desired data.

3 Materials and Methods

The research was carried out by adopting a systematic process-based approach. The research process designed is provided in Fig. 1. The proposed CKMF framework is constructed by studying various KM models and integrating their best features with new ones to overcome their issues. This was further refined by integrating knowledge from the agricultural discipline. A proof-of-concept implementation is carried out to realize the proposed framework. A case study was constructed around the agriculture sector in Pakistan. To evaluate the proposed framework, Information System (IS) model proposed by D&M was considered. It is required to determine the successfulness of a KM system to obtain maximum benefit from it [30]. The constructs of the framework were mapped with framework features to develop the proposed evaluation framework and construct relevant hypotheses.

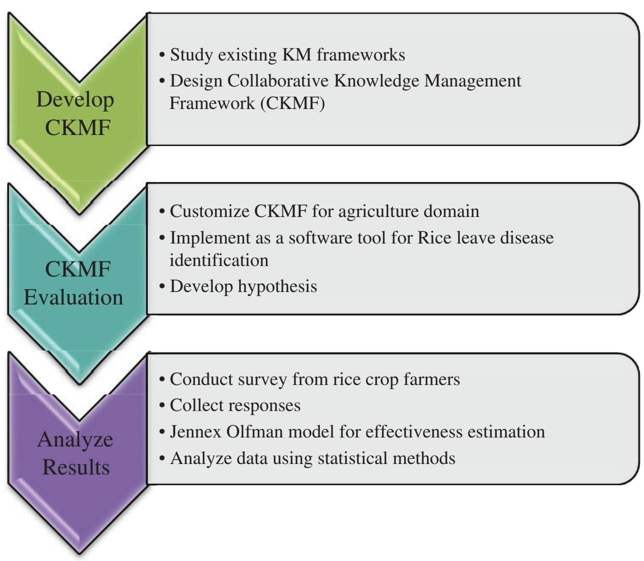

Figure 1: Adopted research mechanism

A field survey was carried out to conduct a walkthrough and collect responses from framers associated with rice production farms. To collect data questionnaire was designed based on evaluation framework constructs. The questionnaires based on hypotheses were completed by 300 rice crop farmers to estimate the effectiveness of the designed software. Using the SPSS tool, quantitative data analysis is performed on the responses collected. The results section reports the details of various tests that were performed, including frequency measures of variables, Cronbach's alpha reliability, and Pearson's correlation.

A 5-point Likert scale is used to measure the latent constructs. All questionnaire items are measured based on the farmers' level of agreement or disagreement, with a 5-point Likert scale ranging from (1-strongly agree to 5-strongly disagree). The measures for the survey constructs are obtained from prior studies, and the questionnaire consisted of two parts. The first part used nominal scales to collect the respondents' demographic information, while the second part consisted of a subjective measure to evaluate the respondents' perception regarding their evaluation of the LCWU aKMS as a KM system. A detailed account of the survey instrument is presented in Appendix A.

The research was carried out to answer the following questions:

a) Study the existing KM frameworks to get gap analysis
b) Develop an effective KM framework (CKMF) to overcome the limitations of existing KM frameworks
c) Proof the effectiveness of CKMF by making its customized implementation in the agriculture sector
    i) Develop a CKMF based software (LCWU aKMS)
    ii) Get user (farmer) feedback for LCWU aKMS
    iii) Perform hypotheses-based evaluation based on KM success model (Jennex Olfman model) and statistical methods
    iv) Check the accuracy of task performed by LCWU aKMS (accuracy comparison of rice leaf disease identification module)

The rest of this section explains the case study used in this research and the hypotheses-based evaluation mechanism.

3.1 Case Study: Existing Agriculture System in Pakistan

Agriculture is the largest contributor to Pakistan's economy; most of the population is dependent on this sector [31]. It accounts for approximately 24% of the total GDP and earns the largest portion of foreign exchange for Pakistan. Moreover, a major portion of the workforce is engaged in this sector [32].

ICT can benefit the agricultural sector greatly by helping advance research and assisting agriculture stakeholders in increasing production and supporting environmentally friendly methods. The main challenge faced by the agriculture sector is the lack of good methods for sharing knowledge. Many research activities are replicated due to the lack of an appropriate sharing mechanism [33]. On the other hand, farmers and field workers face problems when communicating their issues and knowledge with each other and the management. Moreover, extension workers, who act as intermediaries between farmers and authorities, further delay the response time. Decision-making for farmers depends upon their tacit knowledge [34]. The second challenge is inefficient procedures for sharing documents and guidance material. Although national agricultural bodies produce documents about the latest techniques for farmers, these documents are not properly distributed and managed [33]. A third challenge is communicating experiences and learning with other farmers and those new to farming, as there is no proper procedure to share and preserve one's learning. Agriculture knowledge is mostly tacit; like knowledge of other domains, best practices are shared without documenting them [35].

Introducing KM technology in agriculture can help manage agriculture knowledge-sharing problems and enhance food production. The timely provision of information can reduce risk and uncertainty for farmers. To engage KM in agriculture, systematic mechanisms need to be developed to generate, capture, and share information [36–38]. The existing agriculture system in Pakistan was studied and it was found that it is difficult for farmers to get help promptly. The information flow for the existing system is presented in Fig. 2.

A research conducted for Punjab-based farmers by CABI South Asia states that the farmers consider themselves to be information and technology deprived [38]. They lack news about new technologies and crop-specific information also had negative views about the use of TV, radio, and newspaper mediums to access information [38]. Moreover, the issues faced by the extension agents include inappropriate incentives, high transportation costs, and insufficient training in technology and communication skills

[38–40]. The research indicated highly positive farmer responses to the idea of using mobile phones to transmit information to farmers and described it as a low-cost solution [38].

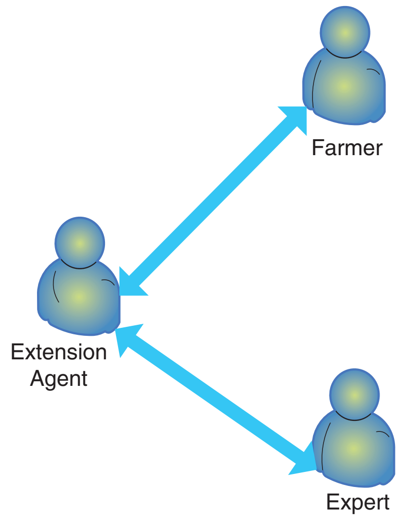

Figure 2: Existing agriculture system

The extension agent system has had little effect on crop production and has failed to develop effective research relationships [31]. Furthermore, extension services have been unable to successfully enhance farmers' technological and technical expertise [41]. Over time, this sector has developed many problems and criticized for its unsatisfactory performance [42].

3.2 Evaluation Model and Hypotheses

An evaluation model is required to estimate KM success. KM systems are considered a type of information system and the Jennex Olfman KM success. The KM success model is an extension of DeLone and McLean's IS success model, which has a reputation as the benchmark for the evaluation of information systems [43–45]. The relationships between the constructs of the Jennex Olfman KM success model were used to develop the hypotheses to evaluate CKMF. The evaluation model presented in Fig. 3 is designed to validate and assess LCWU aKMS.

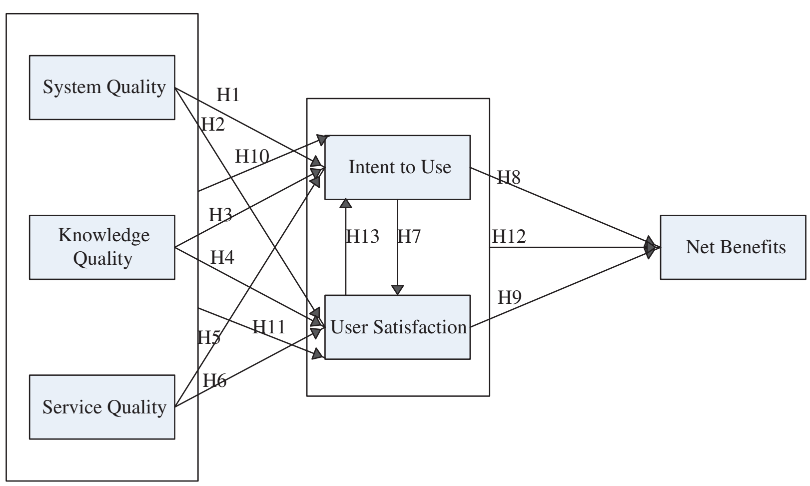

Figure 3: Evaluation model for LCWU aKMS

LCWU aKMS was implemented for the test case and responses were subsequently gathered from farmers using the system. These responses were collected using a questionnaire based on the designed hypotheses.

3.2.1 System Quality (SQ)

Defines how well the system performs the KM activities of knowledge creation, storage, retrieval, sharing, and application [46]. Technological resources include the ability of the organization to develop, operate, and maintain KM [43,46,47]. To determine the system quality of the LCWU aKMS, it is hypothesized that:

H1–There is a positive relationship between system quality and intent to use LCWU aKMS.

H2–There is a positive relationship between system quality and user satisfaction with LCWU aKMS.

3.2.2 Knowledge Quality (KQ)

Responsible for ensuring the right knowledge with sufficient context is gathered and is available for the right users at the right time [46,47]. For LCWU aKMS proposed hypotheses for knowledge quality are:

H3–There is a positive relationship between knowledge quality and intent to use LCWU aKMS.

H4–There is a positive relationship between knowledge quality and user satisfaction with LCWU aKMS.

3.2.3 Service Quality (SVQ)

Ensures that KM provides appropriate user support to effectively benefit from KM [47]. The following hypotheses are developed for service quality:

H5–There is a positive relationship between service quality and intent to use LCWU aKMS.

H6–There is a positive relationship between service quality and user satisfaction with LCWU aKMS.

3.2.4 Intent to Use/Perceived Benefit (IU)

This is a measure to obtain users' perceptions of the benefits of KM, which help predict continued KM use. It helps measure the relationships between social factors involving knowledge use, perceived KM complexity, and benefits of knowledge use [47]. LCWU aKMS is evaluated for this measure using the following hypotheses:

H7–There is a positive relationship between intent to use and user satisfaction with LCWU aKMS.

H8–There is a positive relationship between intent to use and net benefits of LCWU aKMS.

3.2.5 User Satisfaction

User satisfaction dimension is used to measure users' fulfilment with the KM system. It helps to measure KM use, as a desire to use KM depends on users being satisfied with KM [47]. The hypotheses for the user satisfaction dimension are:

H9–There is a positive relationship between user satisfaction and net benefits of LCWU aKMS.

H10–There is a positive relationship between system quality, knowledge quality, service quality, and intent to use LCWU aKMS.

H11–There is a positive relationship between system quality, knowledge quality, service quality, and user satisfaction with LCWU aKMS.

H13–There is a positive relationship between user satisfaction and intent to use LCWU aKMS.

3.2.6 Net Benefits

The net benefits are associated with the use of knowledge may have good or bad benefits; feedback from these help organizations improve their KMS. Using the KM system has an impact on the individual and hence on the organization, therefore it is important to measure it and get feedback [47]. Success impact is measured for four KM areas including leadership, KM strategy, KM content, and process impact. This dimension provides feedback to the respective dimension so that adjustments can be made [47]. The hypotheses for net benefits assessment of LCWU aKMS are as follows:

H12–There is a positive relationship between intent to use, user satisfaction, and net benefits.

H14–There is a positive relationship between system quality, knowledge quality, service quality, intent to use, and net benefits of LCWU aKMS.

H15–There is a positive relationship between system quality, knowledge quality, service quality, user satisfaction, and net benefits of LCWU aKMS.

4 Proposed Solution–Collaborative Knowledge Management Framework (CKMF)

The proposed CKMF depicted in Fig. 4, consists of five layers that cover the overall flow and management of knowledge in LCWU aKMS software. It is customized for agriculture domain, the purpose of customizing the CKMF is to overcome the challenges in agriculture domain presented in the previous section by replacing the extension agent with a CKM system. The Internet, computers, and smartphones are now widely available. The proposed system aims to automate assisting the agricultural sector.

Using the proposed solution, a farmer can directly communicate with an expert. Moreover, a farmer can access stored information to get help and share experiences with other farmers using this platform. At the other end, experts can view and answer farmers' queries, and also view and update the help materials provided to system users. LCWU aKMS was developed based on CKMF. Screenshots of LCWU aKMS are provided in Appendix B of this paper. The prime roles in this system are Farmer (Person who is the requester of information) and Expert (Individual who works as facilitator for the farmer).

Layers of CKMF and their customization for rice leave disease detection are discussed below.

4.1 Interface Layer

The interface layer includes functions related to connection, access, and transformation controls. This layer forms the gateway, communication with the external world and the system is conducted through this layer. It contains settings for the user and device controls. This layer performs the functions of User Authentication, Portal Interface, Role-Based Access Control (RBAC), and Transformation Characteristics.

Customized CKMF Interface Layer: Using the **user authentication** feature, a farmer can be registered and subsequently use the login details to access the system. The **portal interface** is used by the farmer to interact with the system, where farmers can view and utilize the LCWU aKMS functionality with the interfaces. The **RBAC** functionality validates farmer and expert credentials by verifying user names and passwords. The **transformation characteristics** help to vary the ways it presents information on various devices, including smartphones, laptops, and desktop systems.

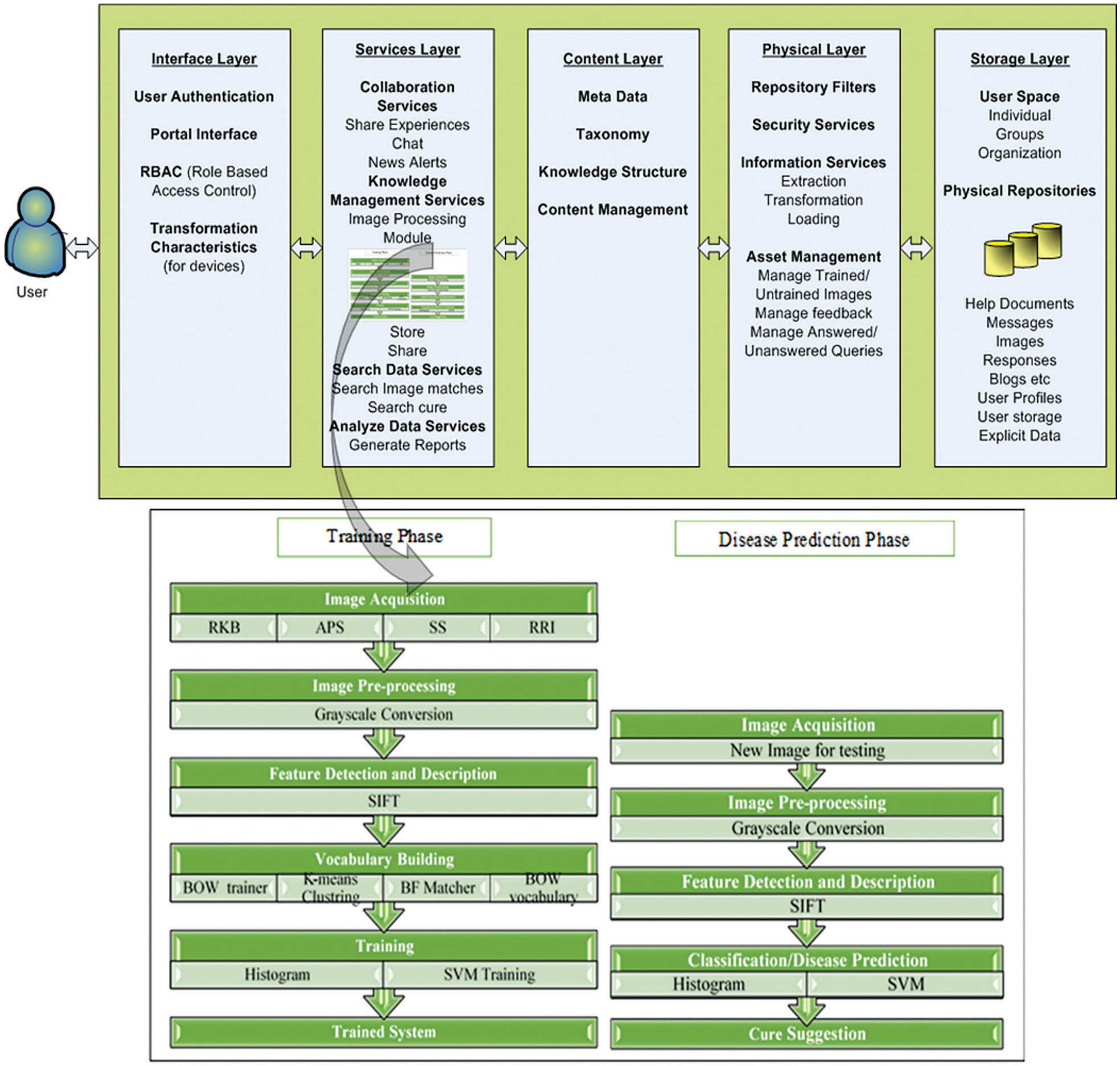

Figure 4: Collaborative knowledge management framework (CKMF)

4.2 Services Layer

This layer provides the primary services of the framework. These services facilitate communications, KM, searches, and data analyses. The services layer holds the KM functionality, with all tasks (i.e., acquisition, generation, elaboration, storage, and sharing) related to knowledge are managed by this layer. The services layer provides primary services of Collaboration Services, Knowledge Management Services (knowledge acquisition, knowledge generation, knowledge elaboration, knowledge storage, and knowledge sharing), Data Search Services, and Data Analysis Services.

Customized CKMF Services Layer: **Collaboration services** involve communicating and sharing ideas for better performance and education of stakeholders. These tasks are achieved by implementing the following features in LCWU aKMS software (based on CKMF): Chatting (two-way communications), Sharing Experiences (Blogs), News Alerts (Broadcasting), and downloadable help documents provided for user guidance. **Knowledge Management Services** form the primary component of a KM system. The image acquisition step includes the process of gathering infected rice leaf images to implement the proposed workflow. Farmers can post problem descriptions along with images of infected rice leaves. Pre-processing is performed to remove noise from the rice leaf images. Diseases are identified based on feature matching by constructing a histogram of a new image and comparing it to histograms of already learned images. The system decides to suggest a cure based on the identified disease information shared by experts. Precautionary measures and cures are gathered from agricultural experts. The resulting knowledge is stored in the knowledge base for future reference and sharing. Disease data in the knowledge base are subject to ongoing updates based on experts' recommendations. This feature facilitates sharing of previously-stored knowledge, supporting continuous improvements, and helping users make decisions. LCWU aKMS has the ability to new learn images, store their information and answer the farmer queries using this information. Moreover, it can learn new diseases after expert verification. This process is explained in Algorithm 1.

Algorithm 1: Leaf Disease Learning (LCWU aKMS)

Step 1: Image Acquisition

a) Get image and description from 'new' folder

Step 2: Image Preprocessing

a) Standardize the color scheme
- Grayscale conversion

Step 3: Feature Detection & Description

a) SIFT
- Extract image regions/features
- Add a description to image regions

Step 4: Vocabulary Building

a) K means (Image Segmentation)
- Categorize data elements
- Set cluster count = 80
- Set cluster type = 'pp centers'
- Form clusters

b) BOW
- Add a visual word with each cluster
- Create visual Bag of Words

c) BF Matcher (Matching Features)
- Group features/clusters
- Find the closet descriptor to each group
- Set BF Matcher Type = 'L1'

Step 5: Training Histogram

a) Make Histogram of clusters
   - Numeric descriptor for image

b) Perform Classification
   - SVM Training
     - Set SVM kernel type = 'RBF'
     - Set nu value = 0.8
     - Set C value = 20
     - Set gamma value = 10

The farmer may request identification of a disease in a rice leaf, by providing an image of the leaf as input to the system. After receiving a request from the framer, the system checks its knowledge base for a matching answer. The information retrieved from the knowledge base is then transferred to an expert for approval. The information received from the expert is refined and stored in the knowledge base for future referencing and is also sent to the farmer as the answer to the query. Algorithm 2 shows this process.

Algorithm 2: Leaf Disease Detection using LCWU aKMS

Step 1: Image Acquisition

a) Get an image from the farmer

Step 2: Image Preprocessing

Step 3: Feature Detection & Description

Step 4: Vocabulary Building

Step 5: Training Histogram

Step 6: Expert Verification

a) if the disease is correctly identified then
   - Send sure suggestions to the farmer
   - Get farmer feedback
   - Store farmer feedback

b) else
   - Get disease details from expert
   - Rename image label
   - Define disease class and cure
   - Store in 'new' folder for learning
     - Learn image as a new disease in next learning

Other requests from farmers could be to obtain help material or share ideas with co-farmers. Farmers can also generate feedback after getting a response from the system, which will help improve the system and data analysis.

Search Data Services help users locate the information of their interest, LCWU aKMS facilitates searching for matches for a given diseased leaf and searching for the cure for the identified disease

Analyse Data Services help users to analyse the collected knowledge, with the system generating reports based on various filters. LCWU aKMS software provides analysis reports based on the following criteria:

- By date, according to the date of a farmer-provided image
- By region, by tehsil, covering all tehsils of Punjab Province
- By disease, producing a report for occurrences of a certain disease in all regions of Punjab

4.3 Content Layer

This layer contains Metadata, Taxonomy, Knowledge Structure, and Content Management. It holds all content-related tasks performed by the CKMF. The objective is to ensure the effective arrangement of information in the knowledge base to make it a useful source of knowledge for users.

***Customized CKMF Content Layer*: Metadata** refers to explanations of valid data formats, showing the types of data that will be created and may include keywords, like crop name, the disease, and the region. **Taxonomy** involves business rules for storing and managing data; for LCWU aKMS, data are classified into images, diseases, and documents. **Knowledge Structure** indicates how knowledge is maintained and in the developed software, knowledge is arranged by disease. **Content Management** is the system's general data management, including rules for validating new data, updating existing records, handling unwanted entries, obtaining and managing supporting materials. This layer is responsible for the arrangement of images and analysis results. It manages the storage of new images and controls the movement of learned images to trained data storage from new images storage location.

4.4 Physical Layer

Physical layer contains settings for physical resources and search, filtering, and resource management services. Internet is used as the backbone for all information flows. This layer controls Repository Filters, Security Services, Information Services, and Asset Management-related features.

Customized CKMF Physical Layer: **Repository Filters** perform checks on data to be stored and retrieved from the system database. It controls the image matching process by responding to queries for images of interest. **Security Services** consists of specific checks, such as the username and password being authenticated for system usage. **Information Services** control information flows in the system, consisting of extraction of valid data, transforming extracted data into the desired form, and communicating answers to experts and users. **Asset Management** is the physical management of system data. LCWU aKMS manages images in the training and test datasets, feedback, answered and unanswered queries, help documents and expert opinions as assets.

4.5 Storage Layer

The storage layer is responsible for the management of storage locations that hold the framework's critical resources. It manages User Space (individuals, groups, and organizations) and Physical Repositories.

Customized CKMF Storage Layer: **User space** is managed for the following three user types:

Individual-Storage space allocated to a single user, such as a farmer or an expert.

Groups-Storage space is allotted for a group of experts and farmers, with members permitted to share stored resources.

Organization-Could be allocated to farmers and experts working in the same organization.

Physical Repositories hold the actual resources stored in databases. LCWU aKMS holds the following resources in repositories: help documents, messages, leaf images, feedback, discussion forums, user profiles, and user storage.

5 Results

This section provides an overall success measure for the software and hence evaluates the CKMF from the KM perspective. The responses collected are statistically analysed to evaluate and assess LCWU aKMS. Tab. 2 lists the demographic information collected from the respondents.

Table 2: Demographic characteristics of the sample, information about rice farmers responding to the designed questionnaires

Variables	Categories	Frequency	Percentage (%)
Experience	above 30 years	43	14.3
	20–30 years	125	41.7
	10–20 years	98	32.7
	above 5 years	28	9.3
	less than 5 years	6	2
Village	Joyian	81	27
	Merajke	2	0.66
	Chak	1	0.33
	Ahmed Pur	4	1.33
	Khokhar	2	0.66
	Jhamat	4	1.33
	Gang	2	0.66
	Dinga	1	0.33
	Bhako Bhatti	16	5.33
	Chawinda	111	37
	Warsalaky	11	3.66
	Maral	14	4.66
	Joshan Jattan	7	2.33
	Gull Chandar	11	3.66
	Freed Pur	12	4
	Wachooky	6	2
	Behram Pur	9	3
	Dhonay	6	2

Respondents were asked questions to assess the existing procedure (before using LCWU aKMS) of extension agent support. Tab. 3 provides the collected information, including frequency of extension agent visits, satisfaction with extension agent, and availability of online help.

Table 3: Responses for extension agent support shows rice framers' response against traditional system of extension agent responsible to provide help and guidance to farmers by officials

Variables	Categories	Frequency	Percentage (%)
Visit frequency	Thrice a month	193	64.33
	Twice a month	106	35.33
	Once a month	0	0
	On call	0	0
Satisfaction from agent	Highly satisfied	0	0
	Satisfied	17	5.7
	Neutral	63	21
	Not satisfied	189	63
	Strongly unsatisfied	31	10.3
Availability of online help	Yes	0	0
	No	300	100

The results showed that most extension agents visit three times a month and farmers are not satisfied with the services they provide. Moreover, the results also indicate online help is not available for farmers.

Reliability of the Research Constructs

The reliability of the instrument is evaluated by calculating the internal consistency of the instrument using Cronbach's Alpha. It is used to show how closely related a set of items are as a group. According to [48], 0.7 is the recommended value for Cronbach's Alpha, but this value could be 0.6 for exploratory research [49]. Tab. 4 gives Cronbach's Alpha for constructs used for CKMF evaluation, its value varies from 0.601 to 0.845, satisfying the internal consistency of the instrument items used to evaluate the CKMF.

Table 4: Cronbach's alpha reliability analysis is given for CKMF, where SQ = System Quality, KQ = Knowledge Quality, SVQ = Service Quality, IU = Intent to Use, US = User Satisfaction, NB = Net Benefits

Construct	No of items	Cronbach's alpha
SQ	14	.814
KQ	19	.805
SVQ	7	.672
IU	5	.601
US	14	.845
NB	13	.760

Pearson's correlation was used to evaluate the linear relationships, direction, and strength of the associations among variables. Tab. 5 shows Pearson's correlation, the results show that a strong direct association exists among the constructs in this study. The 0.01 level shows the correlation coefficients are statistically significant.

Table 5: Pearson's correlation matrix of the variables is shown for the evaluation model constructs

		SQ	KQ	SVQ	IU	US	NB
SQ	Pearson correlation	1	.653**	.544**	.554**	.583**	.495**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	300	299	300	300	300	300
KQ	Pearson correlation	.653**	1	.667**	.555**	.647**	.578**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	299	299	299	299	299	299
SVQ	Pearson correlation	.544**	.667**	1	.622**	.671**	.547**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	300	299	300	300	300	300
IU	Pearson correlation	.554**	.555**	.622**	1	.702**	.585**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	300	299	300	300	300	300
US	Pearson correlation	.583**	.647**	.671**	.702**	1	.704**
	Sig. (2-tailed)	.000	.000	.000	.000		.000
	N	300	299	300	300	300	300
NB	Pearson correlation	.495**	.578**	.547**	.585**	.704**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	300	299	300	300	300	300

Note: **Correlation is significant at the 0.01 level (2-tailed).

6 Discussion

The research work presented in this paper is evaluated against multiple aspects. The discussion section provides arguments about the designed framework i.e., CKMF for the following three aspects:

- CKMF evaluation by comparing its features with the existing KM frameworks
- Evaluation of CKMF based LCWU aKMS software against developed hypotheses
- Accuracy comparison of rice leaf disease identification module of LCWU aKMS with existing techniques

6.1 Comparison of CKMF with Studied KM Frameworks

This section discusses KM features found in the gap analysis for CKMF. KM could occur at different levels; the communication and sharing of ideas make it collaborative in nature. The CKMF supports collaboration at all three levels (individual, team, and organizational). The literature examined showed that there are four modes of knowledge transfer: socialization (tacit to tacit), externalization (tacit to explicit), internalization (explicit to tacit), and combination (explicit to explicit). CKMF aims to address all four types. Tab. 6 indicates the functions of the LCWU aKMS, showing all four knowledge transfer modes.

Table 6: Knowledge transfer in the LCWU aKMS is explained in this table. Various functions are listed along with the type of knowledge transfer performed

User	Function	Knowledge transfer mode
Farmer	Uploads images	Internalization
	Makes queries	Externalization
	Gets answers	Internalization
	Gives feedback	Externalization
	Communicates with other farmers	Socialization
System	Receives requests	Externalization
	Generates results	Combination
	Updates the knowledge base	Combination
	Requests experts	Combination
Expert	Answer's system requests	Externalization
	Updates the knowledge base	Externalization
	Learns about new diseases	Internalization

KM is aided by the IT infrastructure of the organization for effective processing. The technology infrastructure is a combination of data processing, storage, communication technologies, databases, servers, and so on [14]. The final layer of the CKMF framework, referred to as the 'Storage Layer', holds the physical repositories along with other components. It contains the actual resources physically in the databases, including user profile information, help material, user requests, system/expert answers, chats, blogs, and data.

Information communication technology (ICT) tools refer to digital infrastructures that include devices, the internet, and other computing facilities. CKMF framework supports ICT tools, while the developed test case system (LCWU aKMS) supports both mobile and desktop devices. ICT tools are also involved in the image processing phase. Farmers can use their mobiles to take images of the infected leaves and send to system via internet. The help material provided for farmers is downloadable and printer-friendly. Several software features are mapped to CKMF framework including security, built-in help, and clearly defied context. Furthermore, the designed system is flexible, as new features can be easily added. The collaboration features help people communicate and share their ideas, experiences, and problems. This research's goal was to develop a KM framework for collaborative environments. LCWU aKMS supports wikis, blogs, and social software features. Users can share information and data and communicate with each other. Tab. 7 presents a summarized view highlighting various features of the proposed CKMF against the parameters used to summarize existing KM frameworks stated in the related work section above.

Table 7: Summary of the proposed CKMF

KM framework	Critical success factors	Generic	Domain Specific	Technology infra-structure	Multi-level KM	Knowledge transfer	Software features	Collaborative features
CKMF	Partially addressed	Addressed	Addressed	Addressed	Addressed	Addressed	Partially addressed	Addressed

Note: Addressed (green) Partially addressed (yellow) Not addressed (red)

6.2 Evaluation and Assessment of LCWU AKMS Software Using Evaluation Model and Hypotheses

The research questions are analysed by articulating fifteen hypotheses. The results indicate that all hypotheses are well supported. The empirical results of this study indicate a significant relationship among the six constructs extracted from the Jennex Olfman KM success model. The results were consistent with previous IS success model research [50–52], and the literature provides quite strong support for the designed hypotheses [44,46,53,54]. Regression analysis was performed to examine the research hypotheses. Regression analysis is used to measure the relationship between independent variables and dependent variables [55]. Tab. 8 portrays hypotheses are supported by analysing the coefficient of determination (R^2). Independent and dependent variables are also stated for each hypothesis to understand the relationships.

Table 8: Summary of results, showing all the stated hypotheses are supported

Hypotheses	Independent variable	Dependent variable	R Squared	F value	β value	p value	Description
H1—(SQ-IU)	SQ	IU	.307	131.909	.554	<0.01	• *SQ* accounts for 31% of the variation in *IU* • *SQ* had a significantly positive effect on *IU*
H2—(SQ-US)	SQ	US	.340	153.737	.583	<0.01	• *SQ* accounts for 34% of the variation in *US* • *SQ* had a significantly positive effect on *US*
H3—(KQ-IU)	KQ	IU	.308	132.075	.555	<0.01	• *KQ* accounts for 31% of the variation in *IU* • *KQ* had significantly positive effect on *IU*
H4—(KQ-US)	KQ	US	.419	213.947	.647	<0.01	• *KQ* accounts for 42% of the variation in *US* • *KQ* had significantly positive effect on *US*
H5—(SVQ-IU)	SVQ	IU	.387	188.031	.622	<0.01	• *SVQ* accounts for 39% of the variation in *IU* • *SVQ* had a significantly positive effect on *IU*
H6—(SVQ-US)	SQ	US	.450	243.439	.671	<0.01	• *SVQ* accounts for 45% of the variation in *US* • *SVQ* had a significantly positive effect on *US*
H7—(IU-US)	IU	US	.493	289.655	.702	<0.01	• *IU* accounts for 49.3% of the variation in *US* • *IU* had a significantly positive effect on *US*

(Continued)

Table 8 (continued)

Hypotheses	Independent variable	Dependent variable	R Squared	F value	β value	p value	Description
H8—(IU-NB)	IU	NB	.343	155.364	.585	<0.00	• *IU* accounts for 34.3% of the variation in *NB* • *IU* had a significantly positive effect on *NB*
H9—(US-NB)	US	NB	.495	292.159	.704	<0.01	• *US* accounts for 49.5% of the variation in *NB* • *US* had a significantly positive effect on *NB*
H10—(SQ, KQ, SVQ-IU)	SQ, KQ, SVQ	IU	.458	83.065	.257 .403	<0.0005	• *SQ* and *SVQ* had a significantly positive effect on *IU*
H11—(SQ, KQ, SVQ-US)	SQ, KQ, SVQ	US	.545	117.983	.207 .251 .390	<0.0005	• *SQ, KQ,* and SVQ had a significantly positive effect on *US*
H12—(US, IU–NB)	US, IU	NB	.508	155.513	.577 .180	<0.000	• *US* and *IU* had a significantly positive effect on *NB*
H13—(US-IU)	US	IU	.493	289.655	.702	< 0.01	• *US* accounts for 49.3% of the variation in *IU* • *US* had a significantly positive effect on *IU*
H14—(SQ, KQ, SVQ, IU-NB)	SQ, KQ, SVQ, IU	NB	.444	78.423	.301 .141 .330	<0.000	*KQ*, *SQ* and *IU* had a significantly positive effect on *NB*
H15—(SQ, KQ, SVQ, US-NB)	SQ, KQ, SVQ, US	NB	.521	161.143	.568 211	<0.000	• *KQ* and *US* had a significantly positive effect on *NB*

The survey questionnaire was developed based on hypotheses (adapted from Jennex Olfman model) generated to check the effectiveness of the designed system. The evaluation model depicted in Fig. 3 supports the proposed hypothesis. Moreover, Tab. 8 shows that the hypotheses are supported by the results of the survey estimating the usefulness of LCWU aKMS.

6.3 Comparison of Existing and Proposed Leaf Disease Detection Methodologies

Leaf disease detection is performed by many researchers, this section lists a few of such researches and compares the results with the accuracy of LCWU aKMS rice leaf disease detection technique. LCWU aKMS has shown 94.16% accuracy for rice leaf disease detection. Tab. 9 compares the existing and proposed methodologies.

Table 9: Comparison of existing and proposed methodologies is stated below, it shows 94.16% accuracy for disease detection and identification module of LCWU aKMS

Technique	Crop	Accuracy
[56]	Rice	79.5% (Bayes), 68.1% (SVM)
[57]	Rice	75%
[58]	Grape	92.94%
[59]	Pomegranate	Not given
[60]	Rice	91.1% (SVM), 93.33% (KNN)
LCWU aKMS (proposed methodology)	Rice	94.16%

Fig. 5 shows the comparison graph of rice leaf identification techniques.

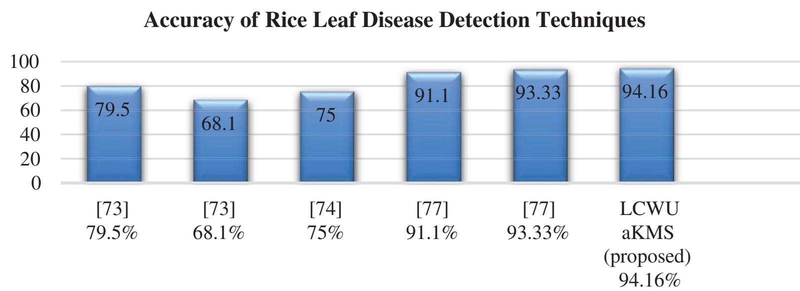

Figure 5: Comparison of rice leaf detection techniques

7 Conclusions

KM has proven its beneficial worth by providing knowledge assets for individuals and organizations. KM is an important multidisciplinary area that contributes towards the integration of knowledge in existing practices by engaging individuals, communities, organizations both related to the private and government sector. Collaborative features coupled with KM features form a strong combination forming a KM system having collaboration features of communication and information sharing. Frameworks play a dynamic role in developing any software system. Researchers have designed several KM frameworks focusing on aspects like critical factors, knowledge level, software features, etc. This study focuses on presenting a generic collaborative KM framework termed CKMF, based on existing frameworks' gap analysis. The Paper also provides evaluation for CKMF using three different aspects. The proposed CKMF framework is customized for implementation in the agriculture domain by taking a case study of Pakistan. The KM is well received in various areas such as education, medical, software development, etc. However, certain disciplines still need to integrate KM practices and frameworks to refine their work practices and acquire results that contribute towards economic growth. In this regard, agriculture is an important area particularly in the context of developing countries where a large population is associated with agriculture.

The empirical evidence in the current study suggests that an increase in system quality, knowledge quality, and service quality increases intent to use and user satisfaction, which increases the net benefit of the KMS. The research work provided practical implementation of the stated concepts of CKMF. LCWU aKMS accurately detected the diseased spots present (if any), classified the type of the disease affecting the leaf, and suggested cures were provided for the diseases identified. The disease detection module is evaluated using the precision and recall method and found to be 94.16% accurate. The results obtained may help farmers be more effective in decision making, more efficiently protecting their rice crops from substantial damage. The system could replace the work of extension agents, making it a cost and time-effective initiative for farmer betterment.

The methodology presented can aid in precision agriculture by forming the basis for rice disease KM. LCWU aKMS provide a platform for farmers for collaborative communication and sharing. CKMF could be customized for KM activities in other domains like education, medicine, media, software houses, and others.

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Appendix A: Survey questions

Construct	Item name	Questionnaire items	Reference
System quality	SQ1	Information I get from the system is clear	[53–54,61]
	SQ2	The system results in accurate predictions of diseases.	
	SQ3	The system provides me with sufficient information.	
	SQ4	The system provides me with up-to-date information.	
	SQ5	The system provides reports that seem to be just about exactly what I need.	
	SQ6	The system allows me to search both people and knowledge.	
	SQ7	Search results are displayed in a timely manner.	
	SQ8	System response time is satisfactory.	
	SQ9	Software packages are updated with recent updates.	
	SQ10	The processing capabilities of the system meet my needs.	
	SQ11	The system provides a portal.	
	SQ12	The system supports wikis effectively.	
	SQ13	The system has a communicative social network or instant messaging tool.	
	SQ14	The system consumes information from other KM systems to provide new knowledge.	
Knowledge quality	KQ1	Using the system can increase my professional productivity.	[53–54,61]
	KQ2	Using the system saves time.	
	KQ3	Using the system improves my job performance.	
	KQ4	The system provides the required knowledge.	
	KQ5	Knowledge is available via the system when I need it.	
	KQ6	The system allows me and my co-workers to exchange ideas and thoughts on common work practices.	
	KQ7	The system keeps updating so that I can locate newly acquired knowledge.	
	KQ8	Information is filtered accordingly, showing only what users require.	
	KQ9	I can store my findings in the system.	
	KQ10	The system is capable of indexing knowledge according to context.	
	KQ11	The system can model past and present knowledge.	
	KQ12	The system provides mechanisms for long term storage, like databases, etc.	
	KQ13	The system provides relevant results for search queries.	
	KQ14	The system supports searches using natural language.	
	KQ15	The system makes it easy for me to create my knowledge documents.	

(Continued)

(continued)

Construct	Item name	Questionnaire items	Reference
	KQ16	The words and phrases provided in the content are consistent.	
	KQ17	The system represents the content in a logical manner.	
	KQ18	The knowledge and information presented by the system could help me in my work.	
	KQ19	I can clearly understand and use the information provided by the system.	
Service quality	SVQ1	The system clearly understands the needs of users.	[53–54,61]
	SVQ2	The system has up-to-date hardware and software.	
	SVQ3	Using the system gives me confidence.	
	SVQ4	I feel safe about my information while using the system.	
	SVQ5	The system gives individual attention to each query.	
	SVQ6	Guidance is provided for usage of the system.	
	SVQ7	Overall, the quality of services provided by the system meet my needs.	
Intent to Use	IU1	The system is easy to use.	[53–54,61]
	IU2	The system is easy to learn.	
	IU3	It is easy to get the system to do what I want it to do.	
	IU4	The system has sufficient resources for facilitation.	
	IU5	I enjoy using this system because it benefits me in terms of efficiency.	
User satisfaction	US1	The system meets my information processing needs.	
	US2	The system meets the knowledge needs of my area of responsibility.	
	US3	The system is very effective.	
	US4	The system is found to be very efficient for my work.	
	US5	The system provides the precise information I need.	
	US6	The information resulting from queries is sufficient.	
	US7	The system is friendly.	
	US8	I can easily locate the required items on the interface.	
	US9	The system interface provides all the required links to the functionalities.	
	US10	The system generates the output in a useful format.	
	US11	The information is clear to understand.	
	US12	The information is accurate.	
	US13	The information provided is easy to incorporate.	
	US14	Overall, I am satisfied with the system for my work.	

(Continued)

(continued)

Construct	Item name	Questionnaire items	Reference
Net benefits	NB1	The system increased my productivity	[53–54,61]
	NB2	The system has created innovative ideas.	
	NB3	The system helped me meet my needs.	
	NB4	The system helped me improve the management of my work.	
	NB5	Use of this system will have no effect on the performance of my job.	
	NB6	The system can decrease the time required for my important job responsibilities.	
	NB7	Use of the system can increase the quality of output for the same amount of effort.	
	NB8	Use of the system can increase the efficiency of performing job tasks.	
	NB9	Use of the system will increase the opportunity for more meaningful work.	
	NB10	Working with the system is complicated.	
	NB11	The system is found to be difficult to understand.	
	NB12	Using the system involves too much time doing mechanical work like data input.	
	NB13	It takes too long to learn the system operations to make it worth the effort.	

Appendix B: LCWU aKMS screen shots