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Names of Researchers/Members of Research Teams:

- ***Dr. Amal Nasralla, Research & Evaluation Consultant***
- ***Dr. Ahmed Rafee, Knowledge Engineering Consultant***
- ***Dr. Maryam Hazman, Knowledge Engineering Expert***
- ***Dr. Ibrahim Ahmed , Project Manager***
- ***Naglaa Hassan, Communication Manager***

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Prepared by: Dr. Amal Nasralla

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1. Executive Summary

An impact study on KenanaOnline project showed that there is still a gap in achieving rational knowledge utilization as a result of two main requirements: Users' need to avoid the flood of available information and access specific data in order to formulate timely right decisions, and experts and professionals' need to simplify their contributions to grassroots and gain economic benefits. The impact study concluded that in order to achieve an optimal knowledge generation, management and utilization, there is a need to enrich community development portals with Community Expert Systems that would avail specific, accurate, and timely information and at the same time fulfill the promotional and economic needs of knowledge providers. Consequently, the objective for this research project has been set to identify a workable model for building efficient knowledge bases for diagnosing problems through expert systems.

This research project has been designed over two phases; the *Foundation Phase* and the *Piloting Phase*. Documentation has been made throughout the two project phases in order to obtain answers to the seven research questions.

The foundational phase that expanded from March–December 2012 aimed at building a foundational framework for the project by studying international, regional and local expertise in building knowledge bases, identifying challenges and opportunities in the Egyptian context, ensuring pre-requisites, and producing Knowledge Bases prototypes for piloting during the remaining of the project. By the end of the foundational phase, the following products were in place for wider piloting during the remaining of the research project:

1) A user-friendly tool for developing expert systems
2) Knowledge engineering training module and training approach
3) Knowledge bases and expert systems prototypes
4) Two knowledge experts trained in knowledge engineering and developing expert systems.

However, for answering the research questions, the prototypes developed during the foundational phase were used in building the capacity of a wide group of knowledge experts. During the project piloting phase that lasted from January – December 2013, five (5) capacity building and validation workshops were conducted raising the awareness and building the capacity of more than 60 participants. Different training approaches have been used during these capacity building workshops in order to identify the best approach for training knowledge experts on developing expert systems.

Analysis of feedback and perspectives solicited through the project monitoring and evaluation interventions has led to the development of a workable framework for building efficient expert

systems. The framework encompasses three interrelated tiers; *Advocacy, Building Capacity*, and *Construction*. A significant feature of the three-tier model is that each of its components affects the efficiency of the following ones. Therefore, rigorous monitoring of the model implementation is instrumental for the development of efficient expert systems.

The first tier in the workable model is concerned with advocating the significance of expert systems for both experts as well as end users. This first tier addresses the power of the advocacy message and the significance of availing multiple advocacy channels. This tier includes three components; namely, *Identification of Knowledge Experts*, *Advocating Business Model*, and *Showing Prototypes.*

While the first tier in the workable model develops a positive attitude towards expert systems, the second tier builds relevant knowledge and skills. Although the second tier in the workable model could be presented as a stand-alone capacity building process, nevertheless, this tier gets much affected by the advocacy efforts as the stronger the advocacy efforts (as presented in the advocacy message and various advocacy channels), the more the quality of the input (as presented in specialized, valid and up-to-date knowledge). Tier two of the workable model also consists of three components; namely, *Setting Training Requirements*, *Training on Knowledge Engineering* and *Establishing Follow-up Mechanism*.

Moreover, the research project places a high emphasis on the third tier of the workable model that is concerned with the construction of the expert systems to avoid the classic mistake of putting the emphasis on the capacity building efforts per se. It is in this tier that the capacity building effort is put under the real-time test. The efficiency of the developed expert systems reflects to a great extent the effectiveness of the capacity building efforts. This third and last tier is comprised of another three components; namely, *Developing, Reviewing and Updating Expert Systems,* *Validation and Verification*, and *Community Rating*.

2. The Research Problem

The different facets of the agriculture constraints in Egypt have resulted in a two-fold challenge; on one hand, farmers losing control over the food crops they have developed over many years due to their failure to resist pests and drainage, and on the other hand, consumers finding it increasingly difficult to locate and purchase safe and healthy food. Consequently, achieving a sufficient increase in the agricultural productivity in Egypt has become a must.

An effective combination of knowledge management concepts and approaches and ICTs tools has been looked upon as a possible way for addressing food security problems through providing adequate and sustainable knowledge that can lead to optimal utilization of water resources and availing latest and timely pests resistance and drainage methods. In Egypt, the idea of using knowledge management in the form of Experts Systems for simplifying the low productivity problems, systemically solve the problem, experimenting with new approaches and transferring experiences and best practices of others has been tried out since the early nineties. However, while the outcome of those attempts was to improve communication between extension, research, private and public sector and institutions involved in rural and agricultural development for the benefit of farmers and agrarian businesses at rural and village level, a final evaluation showed that the network sustainability and expansion faced a challenge as the model had no self-generating profit mechanism. In addition, some researchers predicted that the extension system will lose 50% of its workers due to retention and promotion within the following five years, thus the communication mechanism will lose a main source of its knowledge supply.

Since sustainability and accountability were vital factors that were not met in past projects that aimed to provide agriculture community with timely, updated and sufficient knowledge, Egypt ICT Trust Fund took these two factors into account in developing its community development portals through its KenanaOnline project. Aradina (www.aradina.net) is one of these portals which specializes in Agriculture, Livestock and Fisheries and provides the community with Arabic e-content in the form of articles, links, images and videos classified and displayed dynamically depending on the user preferences and relevant to the required theme. The main working mechanism is through addressing local communities' needs and activating the community contributions including NGOs, users, experts, and professionals. The community contributions are administrated and supervised by the portal editorial team who follows standardized monitoring and motivations mechanism in order to encourage the agriculture community to generate, share and network its knowledge and experiences.

An impact assessment study on KenanaOnline in 2011 showed that in spite the fact that kenanaonline succeeded in providing the community with needed online platform that facilitated professional website creation for knowledge transfer, there is still a gap in achieving rational knowledge utilization.

This gap is the result of two main requirements; 1) Users' need to avoid the flood of available information and access specific data in order to formulate timely right decisions, 2) Experts and professionals' need to simplify their contributions to grassroots and gain economic benefits. The impact study concluded that in order to achieve an optimal knowledge generation, management and utilization, there is a need to enrich community development portals with Community Expert Systems that would avail specific, accurate, and timely information and at the same time fulfill the promotional and economic needs of knowledge providers. The research problem for this project has been identified as such:

The lack of a workable model for building efficient and updated Knowledge Bases for sustainably solve problems in specific knowledge domains.

2.1 Research Objective

The research objective for this project stems from the belief that building and maintaining Knowledge Bases that are efficient and effective in answering questions and solving problems in specific knowledge domains is a *process* where many components come into play creating a web of factors that could affect the efficiency and effectiveness of these knowledge bases. In other words, from a developmental perspective, the need is not simply to get a group of experts to build a number of knowledge bases since this will raise the challenge of maintaining and upgrading those knowledge bases over time and the need to build many more knowledge bases in the different knowledge domains. The objective then should be to identify *how to* go about building efficient and effective Knowledge Bases. This will allow for not only developing the capacity of building knowledge bases in different domains, but also maintaining and expanding the developed knowledge bases as the knowledge evolves.

While this research project aims at developing a number of Knowledge Bases in the agriculture domain through the use of Expert Systems, it also sets itself for documenting the process of building those Knowledge Bases as well as evaluating them in order to consolidate lessons learned. Consequently, the research objective for this project is to:

Research Objective:
Identify a workable model for building efficient Knowledge Bases for solving problems in specific knowledge domains through the use of Expert Systems.

2.2 Research Questions:

The research process has led to some edits in the research questions that were initially phrased in the research proposal. The research questions that this research project is addressing are:

Research Questions

1) What are the components of a workable model for building efficient Knowledge Bases for solving problems in specific knowledge domains through the use of Expert Systems?

   1.1 To what extent do the model components affect each other?
   1.2 What is the expertise needed for managing and sustaining each of the model components?

2) What are the criteria of the knowledge domains that could be best encoded through Expert Systems?

3) What are the selection criteria of the knowledge experts who can effectively encode their expertise as Expert Systems?

4) To what extent is the knowledge engineering methodology adopted in the project effective in capturing and encoding expertise as rules in knowledge bases?

5) What are the advantages and disadvantages of the available Expert System technologies? On what basis the decision was taken for the expert system technology used in this project?

6) What are the competencies and skills required for the efficient use of Expert Systems?

7) How could the challenge of upgrading and sustaining Expert Systems be dealt with?

3. Progress towards Milestones

This research project has been designed over two phases; the *Foundation Phase* and the *Piloting Phase*. Documentation has been made throughout the two project phases in order to obtain answers to the seven research questions.

3.1 The Foundation Phase (March – December 2012)

This phase aimed at building a foundational framework for the project by studying international, regional and local expertise in building knowledge bases, identifying challenges and opportunities in the Egyptian context, ensuring pre-requisites, and producing Knowledge Bases prototypes for piloting during the remaining of the project. This phase comprised the following key interventions.

- Literature Review and Situation analysis
- Developing Expert System Tool
- Selection of micro topics
- Selection of knowledge experts
- Developing knowledge engineering training suite prototype
- Building capacity in knowledge engineering
- Producing Knowledge Bases prototype

3.1.1 Literature Review and Situation analysis

Literature review has been conducted at the outset of the project along with a SWOT analysis in order to identify the key components of building Knowledge Bases through experts systems and the pre-requisites for such a process. The review identified the main causes behind the lack of a workable model for building efficient Knowledge Bases. The causes are outlined under four main headings; causes related to Tools and Technologies, Domain Experts, Knowledge Acquisition, and System Usage (Literature Review & Situational Analysis Document found in Annex 1)

Causes of the Research problem:

1.Tools and Technologies

a. Difficult human interface
b. Critical selection of an Inference Engine well-matched with users' requirements
c. Steep learning curve required for mastering Expert System Shell
d. Difficulty in Knowledge Base maintenance due to wrong selection of knowledge representation and elicitation method.
e. Lack of expertise required for development, deploying, and maintaining the expert system infrastructure.

2.Domain Experts

a. Lack of interest due to non-existing business model
b. Inability to express own reasoning process and / or inconsistent knowledge

3.Knowledge Acquisition

a. Lack of expertise in Knowledge Engineering methods
b. Lack of integrated environment for building and testing KBs.
c. Knowledge engineers needs to study more in depth about the knowledge domain
d. Knowledge Bases require constant domain expertise availability

e. Wrong selection of Knowledge Domain
   i. Selected knowledge domains are not specified
   ii. Selected domains do not have well-defined problems and solutions
f. Lack of training material essential for building capacities in knowledge engineering

4.System Usage

a. Selection criteria of expert system application
b. Insufficient training about the expert system usage
c. Insufficient promotion / advocacy about the expert system benefit
d. Users lacking the required observation skills to provide the ES with answers essential for reaching successful identification of the problem.

3.1.2 Developing Expert System Tool

The process of selecting and adapting the Expert System Tool started with an assessment of the elements of human interface that should exist in such a tool; namely, intuition, user-friendliness, easy-to-learn, visual interface, efficiency and reliability. In light of these elements, a tool has been selected from the available outsource technology for expert systems. The project adopted a work approach that employed different rounds of assessment for the Expert System Tool; assessment by an Expert System Technical Advisor, a number of knowledge engineers at CLAES (Central Laboratories for Expert Systems) and by the knowledge experts who used the tool to develop their knowledge bases. Several tiers of modifications have been made to the Expert Systems Tool in light of feedback received from technical advisor, knowledge engineers and knowledge experts. Feedback on the tool is still on-going through a users' rating mechanism that has been added to the tool to collect feedback from wider pool of users.

3.1.3 Selection of Micro Topics

One of the significant lessons learned that has been identified from evaluating previous attempts in building expert systems is the need to specify micro topics that have specific well-defined problems and solutions. It is also instrumental that the selected micro topics present existing problems for end users (i.e. farmers and extension) and there is a demand for solutions for these problems. For the foundational phase of this research project, micro topics have been selected for four (4) crops; Onion, Barley, Pomegranate, and Tomato. The table below shows the number of micro topics (i.e. disorders) under each of the four crops for which knowledge bases were developed during the foundational phase.

Crop	Number of Disorders	Number of attributes	Number of Rules/Rules with OR
Onion	8	13	16 /3
Barley	6	13	10
Pomegranate	5	7	5/2
Tomato	11	9	11/5

3.1.4 Selection of Knowledge Experts

Some hypotheses were laid out for this research project in regard to the pre-requisites of the knowledge experts who could be best trained on developing expert systems. The initial thought was that knowledge experts who have successful experience in publishing specialized content on *Kenanaonline* community portals should be the best candidates for training in knowledge engineering since they demonstrate knowledge sharing experience and are equipped with IT skills in their dealing with *Kenanaonline* technology. Accordingly, prominent contributors to *Aradina* – one of *Kenanaonline* portal that specializes in Agriculture, Livestock and Fisheries – were brought in for interviews. The interviews aimed at assessing the candidates' level of specialized knowledge and their ability to express reasoning. These criteria together with IT background and experience in sharing specialized knowledge with end users were put into testing through this research project. Consequently, two candidates were selected to be trained in knowledge engineering during the foundational phase; one agricultural expert who works as a senior researcher in the Agricultural Research Center and who has previous experience in uploading specialized agricultural content on Aradina portal, while the other knowledge expert is an agricultural engineer with field experience who has no previous experience with *kenanonline* portal.

3.1.5 Developing Knowledge Engineering Training Suite Prototype

During the foundational phase, a partnership has been established with CLAES (Central Laboratories for Expert Systems), part of the Agri-expert systems network of the Ministry of Agriculture. The main tasks of CLAES in this research project were to develop knowledge engineering training package, build the capacity of knowledge experts in knowledge engineering, and assist knowledge experts in developing valid and verified expert systems. A training package was developed that includes presentations and training material on related topics such as expert system life cycle, ultimate users' needs, knowledge elicitation, knowledge analysis, knowledge engineering, expert system development and expert system validation and verification. The training material was piloted during the foundational phase with the two selected knowledge experts. The training approach and material were adopted accordingly for the following rounds of training.

3.1.6 Building Capacity in Knowledge Engineering

The knowledge engineering training material was piloted in training the two knowledge experts during the project foundational phase. The purpose of the training was to enable them to analyze and structure their knowledge and produce knowledge base documents for the underlying expert systems. The scope of each expert system developed was first defined in terms of the disorders that will be diagnosed and the specific symptoms for each disorder. A structured interview approach was used during the knowledge engineering training session in order to identify the knowledge needed for building the knowledge bases. This methodology was applied for the four expert systems that were developed during the training sessions; Onion, Barley, Pomegranate and Tomato.

3.1.7 Producing Knowledge Bases Prototypes

Four (4) expert systems were developed by the two knowledge experts during their training on knowledge engineering and developing knowledge bases. Two expert systems were developed by each knowledge expert. Both experts took long time developing their first expert system in spite the deliberate differences between the two experts regarding their research background and familiarity with knowledge sharing technology through kenanaonline portals.

During the training, the two knowledge experts were made responsible for knowledge acquisition, formalization of knowledge, encoding the knowledge into the tool and updating the knowledge due to some errors discovered in the acquired knowledge. The four developed expert systems were verified and validated through test cases (refer to technical report on expert system verification in the annex). In addition to developing a number of knowledge bases during the project foundational phase for use as prototypes during the rest of the research project, the training on knowledge engineering and expert system development revealed a number of significant points:

- Training on developing expert systems is feasible and it could enhance the knowledge engineering skills of the trainees to the extent that it affects the level of easiness in which they develop their expert systems after they try out developing a first one.

- Both academic researcher and field worker could be trained on knowledge engineering. However, while the researcher tends to use sophisticated terms in describing plants disorders as per academic references, the field worker is more aware of the language of the growers in describing symptoms of the disorders.

- On the other hand, while the knowledge expert with research background is more familiar with the reasoning process and take a relatively shorter time to understand the outlining of the cause-and-effect chains, the field worker needs more practical training on knowledge engineering and the design of knowledge bases.

Hence, by the end of the foundational phase of this research project, the following products were in place for wider piloting during the remaining of the research project:

5) A user-friendly tool for developing expert systems
6) Knowledge engineering training module and training approach
7) Knowledge bases and expert systems prototypes
8) Two knowledge experts trained in knowledge engineering and developing expert systems.

3.2 The Piloting Phase (January – September 2013)

For answering the research questions that have been laid out for this research project, the prototypes developed during the foundational phase were used for piloting the capacity building efforts among a wide group of knowledge experts. During the project piloting phase, five (5) capacity building and validation workshops were conducted raising the awareness and building the capacity of more than 60 participants. Different training approaches have been used during these capacity building workshops in order to identify the best approach for training knowledge experts on developing expert systems.

1) **End Users Workshop (March 2013, Luxor):** The purpose of this workshop was to get feedback from end users (growers and extension officers) on the four expert systems prototypes that were developed during the foundational phase. This workshop was mainly concerned with validating the expert systems by end users. It consolidated feedback to be used in reviewing the training material and training approach for next rounds of training.

2) **Expert System Team Developers Workshop I (April 2013, Cairo):** This workshop was conducted in partnership with Salasel project to build the capacity of five (5) teams of knowledge experts for collectively developing their expert systems. The idea of a group expert system was originated in light of the findings from the foundational phase that highlighted the merits and drawbacks of both academics and field workers in developing expert systems. This workshop aimed at joining the efforts of both academics and field workers and getting them to work together in groups for developing group expert systems.

3) **Extension workshop (June 2013, Cairo)**: The purpose of this workshop was to build the capacity of extension officers on analyzing the knowledge in the extension documents that are being distributed to growers for developing expert systems. This workshop tried out a different approach in knowledge acquisition than the previous one in that it analyzed knowledge in written documents for building knowledge bases. A skill that extension officers need to learn.

4) **Expert System Team Developers Workshop II (July 2013, Cairo)**: This workshop was conducted to complete the development of the group expert systems that started in April workshop. Since different follow-up strategies did not work effectively in communicating with all group members after April workshop, this second workshop took place to get the groups together once again to complete their work on their expert systems.

5) **Verification and Validation Workshop (August 2013, Cairo):** The purpose of this workshop was to train a group of researchers from the center of Agricultural researches not only on expert system development, but also on expert systems verification and validation methodology- an additional part that was added to the training module. Training knowledge experts on verifying and validating their expert systems was a decision taken by the project team following discussions with project partners (i.e.

CLAES & Salasel) and technical consultants on testing the efficiency of the developed expert systems.

3.2.1 Training Approaches

Different training approaches have been tried out during the five capacity building workshops that have been conducted in the piloting phase and the workshop that was conducted in the foundational phase. Following is a list of these training approaches:

- **End Users Validation of Expert Systems**: It was a useful approach to orient end users on the purpose and functions of expert systems and discuss criteria of effective expert systems before collecting their feedback on the developed systems. Preparing the mindset of end users on what should be expected in expert systems helps in getting relevant feedback.

- **Group Expert System:** Findings from the foundational phase indicated that academics tend to use sophisticated terms in describing plants disorders as per academic references while field workers are more aware of the language of the growers in describing symptoms of the disorders. In addition, academics tend to use academic classification of disorders which might not necessarily go with the same sequence of observed symptoms by the end users. On the other hand, academics are more familiar with the reasoning process and take a relatively shorter time to produce an outline of the cause-and-effect chains than field-workers. This training approach aimed at forming teams of academics and field workers in order to group their merits for the development of more efficient expert systems.

- **Workshop Pre-requisites:** After the second round of training, it has been decided to notify knowledge experts of what they have to bring to the workshop in order to facilitate and accelerate the process of knowledge acquisition, knowledge decoding, designing knowledge bases and developing expert systems. Workshop pre-requisites include determination of micro topics, number of disorders that will be covered, complete and up-to-date information about the selected disorders, and a range of photos in high resolution of symptoms of the disorders.

- **Roles Distribution:** One of the drawbacks of group expert system is the lack of accountability. The different members of the group tend to be unclear about what is expected from each of them after the training workshop. After trying different follow-up strategies – including individual phone calls and social media groups- in order to communicate with members of the expert systems groups after April workshop, the second workshop in July applied a new approach which is the distribution of roles among the different members of the group so that each member is accountable for one or more of the requisites for developing expert systems (e.g. content, documents, photos).

- **Peer Review:** The approach of peer review has been applied since the first capacity building workshop during the piloting phase. A peer review questionnaire (see annex) was used at the end of each workshop for knowledge experts to evaluate each other's expert systems. The approach is based on the fact that knowledge experts are the best candidates for validating and verifying expert systems in their domain of specialization. Hence, a decision was taken to include a section in the training module for training knowledge experts on validation and verification methodology so that they can do it for their own expert systems (as an internal validation and verification process) and for their peers (as an external validation and verification process).

3.2.2 Soliciting Feedback

Parallel to the capacity building efforts, monitoring and evaluation interventions took place during the piloting phase in order to collect feedback on the process of building expert systems as well as on the developed systems. Feedback was collected through three instruments that were developed for the purpose of this research project; focus group interviews, training questionnaire, expert system questionnaire (see annex for the evaluation instruments). The following is a list of monitoring and evaluation interventions that have been conducted in this research project

- Focus group meeting with knowledge experts
- Focus group meeting with CLAES knowledge engineers
- Focus group meeting with expert system team developers
- Focus group meeting with agriculture researchers.
- End of training questionnaire for each of the five (5) capacity building workshops
- Peer review questionnaire for each of the five (5) capacity building workshops

4. Synthesis of Research Results

Analysis of feedback and perspectives solicited through the project monitoring and evaluation interventions revealed answers to the seven research questions. Feedback collected from knowledge experts (i.e. researchers, academics, field workers and extension officers) as well as end users, in addition to perspectives discussed with knowledge engineers, project partners and technical experts have all contributed to providing valid answers to the research questions as will be discussed in the following sections.

4.1 A Workable Model

The first research question spells out the main objective of this research project which is to identify a workable model for building efficient expert systems. To that end, the process of building efficient expert systems in this research project has been closely monitored and evaluated in order to elicit a workable framework that could be scaled up in future projects.

Research Question 1: What are the components of a workable model for building efficient Knowledge Bases for solving problems in specific knowledge domains through the use of Expert Systems?

1.1 To what extent do the model components affect each other?
1.2 What is the expertise needed for managing and sustaining each of the model components?

The workable model that has been identified in this research project encompasses three interrelated tiers; *Advocacy, Building Capacity*, and *Construction*. A significant feature of the three-tier model is that each of its components affects the efficiency of the following ones. Therefore, rigorous monitoring of the model implementation is instrumental for the development of efficient expert systems.

4.1.1 Tier One: Advocacy

This first tier in the workable model is concerned with advocating the significance of expert systems for both experts as well as end users. This first tier addresses the power of the advocacy message and the significance of availing multiple advocacy channels. This tier includes three components; namely, *Identification of Knowledge Experts*, *Advocating Business Model*, and *Showing Prototypes.*

- **Identification of Knowledge Experts**

A critical start for the development of efficient expert systems is the identification of suitable candidates who could be trained on building efficient expert systems. It is such a critical step since the research project highlighted various degrees of success in developing efficient expert systems due to a number of factors; namely, IT illiteracy, logical thinking and reasoning skills as well as access to specialized, valid and up-to-date knowledge. While the knowledge engineering training module familiarizes knowledge experts with the expert systems technology and enhances their skills in presenting knowledge in a reasoning sequence, however, basic IT skills, access to specialized, valid and up-to-date knowledge and the ability to present such a specialized knowledge in a reasonable sequence have been identified in this research project as key criteria for selecting suitable candidates for training on building expert systems. Moreover, the research project proved that these criteria could be equally found among academics or field workers alike.

- **Advocating Business Model**

One of the drawbacks of previous attempts in building expert systems that this research project tried to overcome is the lack of a business model that could be communicated to the knowledge experts. This research project set a clear advocacy message during the orientation session at the start of the training module that clearly presents possible returns on investment for knowledge experts who invest their time and effort developing efficient expert systems that could benefit end users. In addition, the advocacy message explores the idea of possible competition between expert systems addressing the same disorders in the near future and how the business model for developing expert systems calls for the development of efficient systems that respond to the needs and satisfaction of end users. Moreover, the advocacy message adopted in this research project addresses the quality of input as presented in the quality of knowledge presented in the expert system highlighting the significance of such knowledge to be specialized, valid and up-to-date. The workable model also stresses the need for using different channels of communication in outreaching to knowledge experts. Different on-line and off-line advocacy channels are instrumental for spreading the message about the significance of expert systems to a wider audience.

- **Showing Prototypes**

This tier in the model for building efficient expert systems gives a considerable weight to prototypes since showing what an expert system is like and how it works fulfills the aim of the advocacy message better than preaching about the significance of expert systems. Moreover, prototypes are good models for best practices and provide a chance for adaptation and variation in building expert systems in other knowledge domains. Furthermore, using prototypes could turn knowledge experts to possible advocates of expert systems among their own communities of specialists.

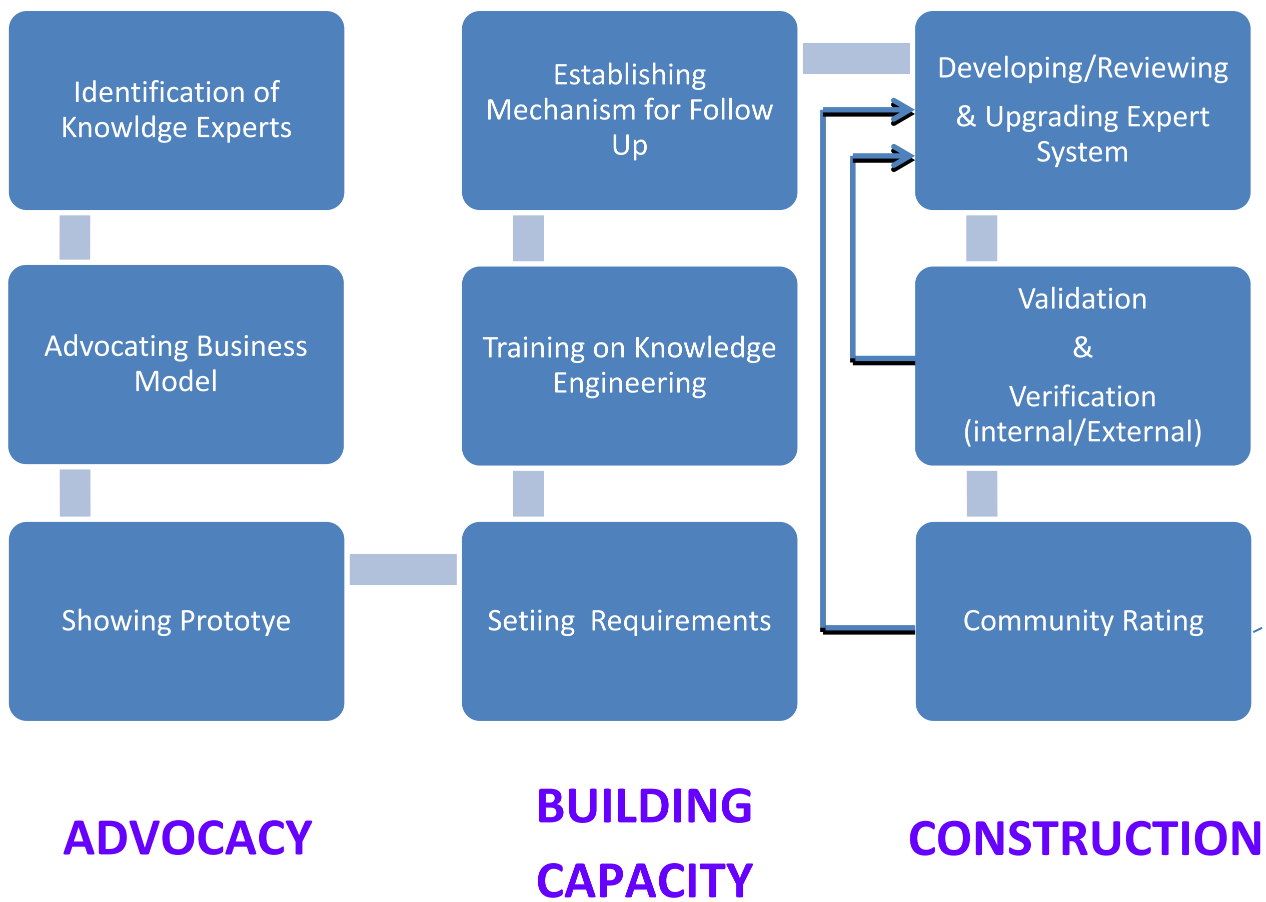
4.1.2 Tier Two: Building Capacity

While the first tier in the workable model develops a positive attitude towards expert systems, this second tier builds relevant knowledge and skills. Although this second tier in the workable model could be presented as a stand-alone capacity building process, nevertheless, this tier gets much affected by the advocacy efforts as the stronger the advocacy efforts (as presented in the advocacy message and various advocacy channels), the more the quality of the input (as presented in specialized, valid and up-to-date knowledge). Tier two of the workable model also consists of three components; namely, *Setting Training Requirements*, *Training on Knowledge Engineering* and *Establishing Follow-up Mechanism*.

- **Setting Training Requirements**

The different training approaches that have been adopted in this research project highlighted the significance of setting pre-requisites for training. Key training pre-requisites are: deciding on the scope of the expert system in terms of the micro topic and the disorders that the expert system will address, preparing relevant linear and non-liners knowledge (e.g. photos) and preliminary classification of knowledge to form cause-and-effect sequence. Given the significance of such training pre-requisites in facilitating and accelerating the expert system development process, it is highly recommended to prepare an orientation on expert systems to be sent out with invitation for training so that trainees could be best oriented on preparing training pre-requisites.

A Workable Framework for Building Efficient Expert Systems



- **<u>Training on Knowledge Engineering</u>**

Building the capacity of knowledge experts in knowledge engineering is at the heart of the workable model. Previous attempts for building expert systems relied on knowledge engineers for knowledge acquisition, analysis, encoding and decoding knowledge on the expert system tool which proved difficult for the knowledge engineers to build several expert systems in different knowledge domains and in updating the developed expert systems. This research project puts a high weight on the knowledge experts to build their own expert systems in light of the fact that it is more effective to train knowledge experts on knowledge engineering than training knowledge engineers in a specialized knowledge domain. Given the significance of this component in the workable model that has been elicited during this research project, a training module has been designed and piloted with six groups of knowledge experts during the foundational and piloting phases of the research project. The training module includes training sessions on expert system life cycle, ultimate users' needs, knowledge elicitation, knowledge analysis, knowledge engineering, expert system development, expert system validation and verification.

In designing expert systems, specialized knowledge is presented through knowledge bases that includes rules. CLAES were verifying the expert systems through test cases to check system rules are all used and logically and sequentially in order. Due to the significance of validation and verification part in building expert systems, skills for expert systems validation (content) and verification (system) were included in the training module in order for knowledge experts to become more capable of revising the flow of their expert systems through the use of the established rules in identifying gaps in the system design

Trainees' satisfaction with the training module and approach was solicited at the end of each training workshop during the piloting phase of the research project through a training satisfaction questionnaire (see Annex). Analysis of the training satisfaction questionnaires revealed the following satisfaction rates for the five capacity building workshops that were conducted during the piloting phase of the research project

Workshop	Overall Satisfaction Rate	Key comments
End Users Workshop (March 2013, Luxor):	75%	- Longer time for training - Need help in using expert systems
Expert System Team Developers Workshop I (April 2013, Cairo)	70%	- Need help in validating expert system - Need help in updating expert system - Needed time for piloting expert system with end users - Help with knowledge verification -
Extension workshop (June 2013, Cairo)	70%	-Need for an external entity to validate the developed systems
Expert System Team Developers Workshop II (July 2013, Cairo):	85%	-Follow-on training proved useful
Verification and Validation Workshop (August 2013, Cairo):	85%	-Need help in expert system verification and validation

In light of trainees' satisfaction with the training module on expert system development and their feedback, the training module was adapted and a section on expert system verification and validation was included. The training module is placed on CDs for distribution to interested knowledge experts following future advocacy efforts. Nevertheless, the research project highlighted a need for technical support and follow-up mechanisms as an integral part of the capacity building tier of the workable model.

- **Establishing Follow-up Mechanisms**

The research project highlighted the need for articulating technical support plans and follow-up mechanisms for knowledge experts who went through training on developing expert systems. The feedback collected from both knowledge experts and knowledge engineers highlight such a need. In addition, an incentives mechanism should be in place in order to motivate knowledge experts to complete the development and/or update their expert systems after the end of training. Incentives should be in the form of high ranking or good review to the expert systems that are frequently updated. Furthermore, as part of the capacity building tier, a need has been identified to establish an index for rating expert systems so that knowledge experts could relate their expert systems to such an index and work towards a high ranking on the established index.

4.1.3 Tier Three: Construction

This research project places a high emphasis on the third tier of the workable model that is concerned with the construction of the expert systems to avoid the classic mistake of putting the emphasis on the capacity building efforts per se. It is in this tier of the workable model that the capacity building effort is put under the real-time test. The efficiency of the developed expert systems reflects to a great extent the effectiveness of the capacity building efforts. This third and last tier is comprised of another three components; namely, *Developing, Reviewing and Updating Expert Systems,* *Validation and Verification*, and *Community Rating*.

- **Developing, Reviewing, Updating Expert Systems**

In developing expert systems, the need becomes to respond to the interest of the growers; selecting micro topics that respond to problems facing the growers, structuring and ordering questions that could be easily answered by the growers, using clear questions and language familiar to the growers in describing the symptoms of the disorders, including all possible questions and answers that growers could possibly observe and describe, reviewing and updating the expert systems for better ways to respond to growers' needs for diagnosing plants' disorders. In a nut shell, each step in developing, reviewing and updating expert systems should be for more convenient use of expert systems by the end users; the growers. This is what this research project has identified as the ultimate criteria for efficient expert systems.

- **Validation and Verification**

If the efficiency of an expert system is assessed by the extent it satisfies the needs of end users for diagnosing problems with their crops, system validation and verification are concerned with the correctness of the diagnosis in light of the described symptoms and the number of used rules that have been included in the knowledge base of the expert system to enable the system in diagnosing the described symptoms. The initial thought was that an external entity should be responsible for validating and verifying expert systems, however, building the capacity of knowledge experts to validate the knowledge included in their expert systems and verify the rules used for diagnosing the described symptoms have been identified in this research project as an integral part of the construction tier of the workable model since testing expert systems by real time test cases (one positive and one negative) is a good approach for the knowledge experts to adapt their expert systems in light of the test cases. Nevertheless, by highlighting the significance of validating and verifying the expert systems by knowledge experts, the research project has not denied the need for external validators in terms of peer review and users' feedback.

- **Community Rating**

The workable model is concluded with such a high stake component. Community rating of expert systems is high stake since it indicates the need for expert system review and update. With the emphasis on a business model for expert systems development and a fierce competition between knowledge experts, community rating becomes a significant tool for the identification of best practices among expert systems. To this end, the project management team has decided to add a function on the expert system tool that enables expert system users to rate the system in light of its efficiency in diagnosing described symptoms, thus enabling the role of community rating in screening and ranking available expert systems.

4.2 Selection of Knowledge Domains

Research Question 2: What are the criteria of the knowledge domains that could be best encoded through Expert Systems?

The research project has identified some criteria for the knowledge domains that could be best encoded through expert systems. These criteria are:

- Symptoms could be observed when they first occur
- Symptoms could be observed and described by end users
- Symptoms are differential in terms of color, status, spread….etc.
- Symptoms of a given disorder are limited in number and could be distinguished from other sets of symptoms
- Symptoms that occur for more than one cause could be verified by the existence of other sets of symptoms
- Symptoms could be linked to a limited number of root causes

Preferable

- Photos could be taken to the described symptoms at different time intervals

In light of the above criteria, the research project has identified the feasibility of expert systems in diagnosing plants diseases more so than livestock diseases.

4.3 Selection of Knowledge Experts

Research Question 3: What are the selection criteria of the knowledge experts who can effectively encode their expertise as Expert Systems?

The initial hypotheses that have been set out for this research project suggested the selection of candidates who demonstrate successful experience in publishing specialized content on community portals since knowledge sharing experience and IT skills were considered vital criteria for successful training on developing expert systems. However, the research proved the invalidity of such hypotheses since trainees with and without previous knowledge sharing experience on community development portals faced the same challenges and demonstrated similar learning patterns in developing their expert systems.

Instead, the research pinpointed a number of instrumental criteria for the knowledge experts who can effectively encode their expertise through expert systems. Such criteria are

- Familiarity with the described symptoms as experienced by the end users; the growers.
- Awareness of the language used by the growers in describing symptoms of the disorders since the research identified some differences between academics and field workers in the language that each group uses in referring to the same symptoms.
- Acquisition or access to specialized, valid, and updated knowledge.
- Demonstration of logical thinking and reasoning skills.

Furthermore, the research project highlighted some differences between field workers and academics in the sense that field workers are more aware of the language used by the growers in describing the observed symptoms, their ability to break down described symptoms to root causes, and their accurate description of symptoms. On the other hand, academics tend to show higher ability for logical thinking and develop knowledge engineering skills faster.

Given the identified strength of both academics and field workers in developing expert systems, the research project suggested the possibility of forming teams of expert system developers that include academics and field workers. Putting an academic and a field worker in one team will lead to knowledge transfer between the two while they work together to produce an efficient expert system feasible for use by the growers. However, the research project highlighted two key conditions for this approach to work: 1) specifying clear roles and responsibilities for the academic member and field worker in the team, and 2) preserve the ownership of the expert system to be given to all members of the team.

4.4 Knowledge Engineering Methodology

Research Question 4: To what extent is the knowledge engineering methodology adopted in the project effective in capturing and encoding expertise as rules in knowledge bases?

The knowledge engineering methodology adopted in this research project trains on two types of approaches; approaches for knowledge acquisition, and approaches for presenting knowledge in a logical model. Knowledge acquisition approaches are interviews and documents analysis. On the other hand, approaches for presenting knowledge in a logical model include the selection of a knowledge presentation format, adaptation of the selected format and decoding knowledge in the adapted format.

The knowledge engineering methodology depends in interviewing knowledge experts for knowledge acquisition on their presentation of the procedures they take to reach a certain diagnosis. The interviewing approach seeks clarification on any unclear point that needs explanation either through actual observation of the knowledge experts while diagnosing a specific problem or getting the knowledge expert to take notes of all the procedures that have been taken place in diagnosing certain symptoms.

The knowledge engineering methodology adopted in this research project includes two types of knowledge; namely, knowledge related to logical thinking and inferences (infer diagnoses based on described symptoms), and knowledge related to the specific knowledge domain (rules and knowledge bases). Training knowledge experts on knowledge engineering aims at enhancing their reasoning skills in a way that they can analyze their specialized knowledge and present it in logical chunks.

To conclude an answer for this research question, the high satisfaction rate achieved in the capacity building workshops (70% - 85%) indicates that the knowledge engineering methodology adopted in these training workshops should be considered effective in preparing knowledge experts for capturing and encoding knowledge in the form of rules in knowledge bases. However, verification reports by CLAES on the expert systems developed highlight the need for further technical support and follow-up mechanisms for assisting knowledge experts in reviewing their expert system.

4.5 Expert System Tool

Research Question 5: What are the advantages and disadvantages of the available Expert System technologies? On what basis the decision was taken for the expert system technology used in this project?

Literature review indicates that the most efficient expert systems tool is the one that allows for straightforward decoding of knowledge rules on the tool, placing questions in a sequence that allows for asking one question at a time, allow for the upload of photos for better description of symptoms and can support a gallery of photos. In addition, it has been identified that the most efficient expert system tool is the one that allows for work at the level of symptoms and not the level of disease name because the end users do not know the name of the disease, but can describe the symptoms. Consequently, the tool should allow for further questions to confirm the diagnosis.

In light of the above criteria for efficient expert systems tools, the decision was taken for the expert system technology used in this research project. Moreover, the expert systems tool used in this research project allows for changing orders of the questions for better logical inferences. Furthermore, after diagnosing the problem based on the described symptoms, the current tool refers users to related articles in order to give them perspectives into the needed solutions.

4.6 Competencies for Expert Systems Use

Research Question 6: What are the competencies and skills required for the efficient use of Expert Systems?

Given that the main function of expert systems is the fast diagnosis of symptoms for quick interventions, failure to diagnose or false diagnosis could have nothing to do with the system efficiency, but to the inaccurate description of symptoms on the part of system users.

Consequently, it was natural to pose a question in this research project that addresses competencies and skills required from end users for the efficient use of expert systems. Discussions during this research projects highlighted a number of end users' competencies to be better able to answer questions on the expert systems. These required competencies are classified into two groups: a) Before using the expert system, and b) During using the system.

A) Before using the expert system, end users are required to:

- Carefully examine the different parts of the plant (e.g. leaves, stem, roots) and observe all symptoms
- Take clear and organized notes of all the symptoms observed

Preferable:

- Take pictures of the symptoms at different time intervals

B) During using the expert system, end users are required to:

- Provide accurate description of the observed symptoms

- Carefully consider all the multiple choices that the expert system provides and select the appropriate ones
- Answer all the expert system questions accurately
- Carefully examine available photos for the discussed symptoms

Preferable:

- Send feedback on the system diagnosis and rate their satisfaction with the system for system review

However, as the expert systems are getting ready for actual trials by end users, more data should be collected to verify answer for this research question.

4.7 Challenges of Upgrading and Sustaining Expert Systems

Research Question 7: How could the challenge of upgrading and sustaining Expert Systems be dealt with?

One of the classic challenges of expert systems is the challenge of system upgrade and sustainability. This is a significant phase in the life cycle of expert systems since over time, knowledge experts could possibly encounter the same symptoms in many forms and here comes the need for system review and update. The research project identified different approaches to address the challenge of system upgrade and sustainability:

- **Group Expert Systems:**

Encouraging joint efforts between academics and field workers in building group expert systems where roles and responsibilities for system development, review and update is clearly stated. This could distribute the burden of system update and frequent review on more than one person.

- **Peer Reviews**

This approach is based on the fact that knowledge experts are the best candidates for validating and verifying expert systems in their domain of specialization provided they know how to validate and verify expert systems. That is why a section on system verification and validation has been included in the training module to build competencies in peer review. In addition, a peer review questionnaire has been prepared to be placed on the expert systems portals.

- **Technical Support and Follow-up Mechanism**

Technical support plans and follow-up mechanisms should be clearly articulated for knowledge experts who went through training on developing expert systems since these mechanisms will not only assist knowledge experts in reviewing and upgrading their expert systems, but encouraging them to do so in the first place.

- **Community Rating and System Ranking:**

Community rating and system ranking are effective approaches for expert system review given the expected competition between expert systems in attracting traffic and consequently possible business deals with end users. In addition, such approaches are significant for the identification of best practices among expert systems. To this end, a function has been added on the expert system tool that enables expert system users to rate the system in light of its efficiency in diagnosing described symptoms, thus enabling the role of community rating in screening and ranking available expert systems.

- **Incentives Approach**

Incentives could possibly be effective motivation for knowledge experts to update their expert systems. Incentives could be in the form of high ranking or good review to the expert systems that are frequently updated. Furthermore, establishing an index for rating expert systems could be also a good approach to encourage system update and sustainability since knowledge experts could relate their expert systems to such an index and work towards a high ranking on the established index.

5. Synthesis of Results towards AFS Outcomes

In addition to its discrete objective of identifying a workable model for developing efficient expert systems, results from this research project contributed to the following outcomes of the Agriculture and Food security (AFS) Program.

- **New technologies and farming systems and practices**

The research project contributed to new technologies and farming systems and practices through the expert system tool that has been identified and piloted and also through 37 expert systems that have been developed and verified during this research project.

- **Risk Mitigation**

Through the technology of expert systems, the research project has contributed to better risk mitigation for food security by introducing mechanism to diagnose agriculture disorders that could be caused by climate change. Expert systems would provide alternative and quick alternatives to face the impact of climate change on food security.

- **Access to Resources**

The research project contributed to improved access to resources for food production and security through the different knowledge bases presented in the developed expert systems. In addition, the expert system tool that has been adopted in this project refers expert system users to a gallery of photos as well as relevant articles that are considered valuable resources that the agriculture community will have access to through this research project.

- **Income generation**

With quick diagnosis of the problem, growers will be able to handle plants disorders early on preventing the spread of diseases throughout the crop. This quick and early intervention would help the growers in fighting plants diseases promptly resulting in better and bigger harvest that would ultimately affect the growers' income from the growing crops.

- **Information and Communication Technology**

The research project contributed to the provision of equitable use of technologies for the growers with the introduction of mobile application to access expert systems in addition to the on-line access of those expert systems.

6. Problems and Challenges

A number of problems and challenges has been identified in this research project:

- **Validation and Verification of Expert Systems**: The verification and validation process of expert systems is a challenging task as expressed by many knowledge experts. Therefore, help is required for them to conduct validation and verification of their developed expert systems. There is such a foreseen challenge in maintaining working mechanisms with entities such as the 'Agriculture Technology Centre (ATC) at the Ministry of Agriculture or CLAES in providing validation and verification services and technical support to the developed expert systems

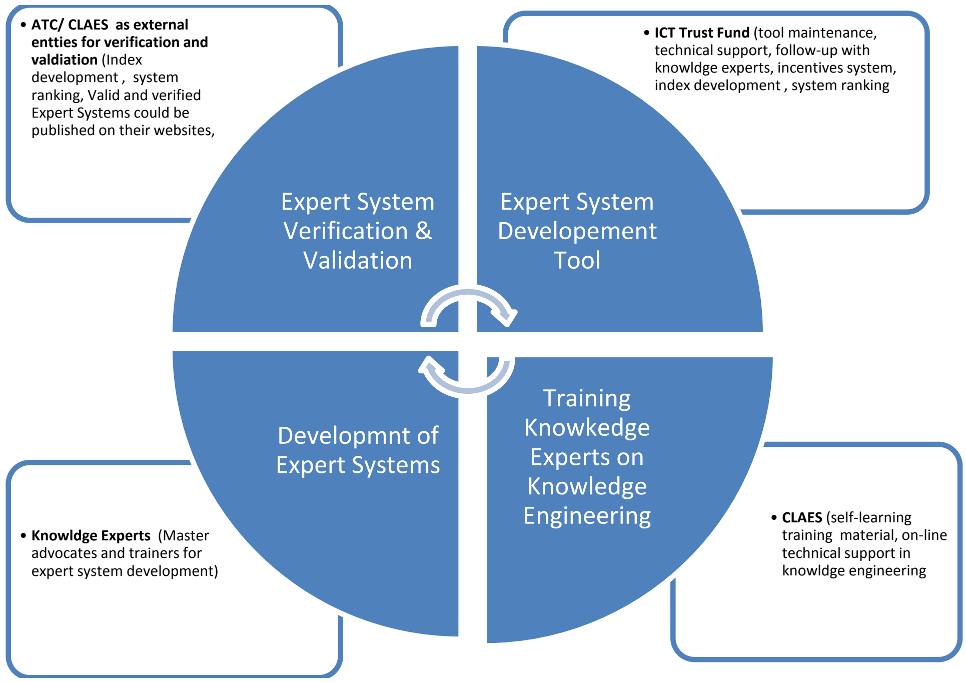
- **Maintaining future partnership among project stakeholders**: Significant partnerships have been established during this research project which resulted in major effect on the project outcomes. The partnerships with CLAES for preparing a training module on knowledge engineering and expert system development and verifying the developed expert systems is one of the significant partnership that will come to an end after the project. Similarly, partnership with a project such as Salasel that facilitated the project outreach to agriculture experts and growers also came to an end with the end of Salasel project. Let alone the role that MCIT had played in preparing the expert system tool and responding to collected feedback on the tool. The inability to maintain such a partnership between project stakeholders after the end of the project is considered a big challenge especially with the inevitable needs for upgrading and reviewing the training module, assistance in verifying expert systems, responding to technical problem with the expert system tools and provision of technical support and follow-up assistance to knowledge experts.

- **Ownership of Group Expert Systems:** With the highlighted value of forming teams of academics and field workers to join effort in developing and sustaining their expert systems, comes the problem of system ownership. Unless the team members are in good working relation, the challenge of preserving the system ownership to all team members will be more than the benefits that could be realized by getting an academic working with field workers for more efficient development of expert systems. This challenge will be further highlighted when business opportunities, as a result of the expert system, reach one of the team member and not the other.

- **Developing Index for Ranking Expert System:** As the need for an index to rank expert systems is increasingly identified, the challenge is who should be developing such an index and how such an index can be updated in the future in order to reflect new requirements that will evolve.

7. Recommendations

In response to the identified challenge of maintaining future partnerships among project stakeholders, the following figure lists roles and responsibilities for a possible working model among different stakeholders.



- Communicate the outcome of this research project with the Ministry of Agriculture for possible linkage with its strategic plan.

- Expand the project to other possible users such as fertilizers companies which can use the expert system to market the suitable fertilizers according to the diagnosed problems. In addition, extension officers throughout the country could be good candidates for training on expert systems.

- Develop an advocacy plan for the dissemination of expert systems to wider group of users through e-leaning modules, CDs, Interactive desk top…etc.

- Continue in collecting and analyzing feedback on the expert system tool and the developed expert systems as they are used by end users.

- Scale up the workable model that has been identified in this research project through a new project that includes beast control, irrigation and fertilization in addition to diagnosis.

- Avail the developed expert systems off-line through establishing partnerships with agricultural NGOs that can provide farmers with access to the developed expert systems.