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Agro-meteorological Knowledge Management System for Small Scale Farmers

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A lot has been done in the use of Information and Communication Technology (ICT) in business yet very little in solving agricultural problems in developing countries. The problem addressed in this paper is the integration of widely available knowledge, processing and providing effective delivery for countries with low ICT infrastructure. Data was collected from small-scale farmers, meteorologists, agricultural extension officers and a research station and analyzed. From this, a suitable knowledge based model was developed. In order to evaluate the model, a prototype was developed and used in tests with sample data. The results reveal that the best way of disseminating agro-meteorological information to small scale farmers is using an integrated knowledge management system and mobile phone technology.

1.0 Introduction

A common problem in developing countries is the lack of integrated means of processing and delivering agrometeorological information to small scale farmers. Even with improved agricultural technology and improved level of farm inputs the agricultural sectors of these countries operate below their potential level owing to the challenges imposed by the marked weather and climate variability. These countries lack a formal system that integrates data from different sources such as agricultural research institutes, meteorological stations, agricultural advisory agencies and the actual ecological requirements. To understand the magnitude of the problem and suggest possible solutions, a study was carried out in Kenya. Kenya has many districts where small scale farming is carried out. Purposive sampling method was used in picking up the district where this research was done [Mugenda and Mugenda 2003]. Simple random sampling technique was used in picking out the respondents during the survey. The survey showed that Information has to be delivered to farmers in a purposeful and meaningful manner that can enable them make informed decisions. It also revealed that majority of the farmers are not able to access meteorological information and even where available processing requires human expertise which is rarely available. The mode of delivery mainly involves mass media especially the radio and is not effective.

This paper therefore addresses the challenges brought about by the above short comings. We specifically address the problem of lack of appropriate system that collects, organizes and disseminates agro-meteorological information to small

scale farmers in a meaningful format. We present a model of knowledge based system that integrates the collection, processing and dissemination of vital agro-meteorological information. It integrates an expert system, and comprehensive knowledge dissemination techniques involving the mobile phone and the internet. A prototype based on the model was developed. This paper also presents the evaluation results of a prototype based on the above model. Through this prototype, we demonstrate that small scale farmers in developing countries can quickly obtain expert information on ecological requirements, pests, diseases and meteorological information by taking advantage of the fast growing mobile phone technology.

2.0 Related Approaches

The challenges of integrating agro-meteorological data in developing countries are wide and varied. Many models have been brought forward but of all the reviewed models, none could comprehensively address the unique challenges in the developing countries. The unique challenges include a large population of rural people with limited access to technology, among many other challenges addressed later in this paper. Most proposed models address agriculture or weather related issues separately. Further they do not treat the aspect of reasoning with the knowledge resident in people and giving focused information a priority. Activities of mainstream research have concentrated on the following basic categories: field data collection and storage, data processing and knowledge dissemination. Majority of the reviewed models propose the use of remote sensory equipment in collecting field data. The upper air atmospheric observation is done by remote sensors carried in special balloon such as that reported by Kenya Meteorological Department [KMD, 2008]. The ground observation is done using remote sensors as reported in Khalid and Steve et al. [2005] among others. Developing countries are unable to easily implement the automatic ground observation techniques due to inadequate level of funding. The spread of mobile telephones seems an attractive option for collecting weather data in the field and sending it to a centralized database. After processing, the knowledge may be disseminated through short message service as reported by Hansen and Jensen. [2002]. This information should be combined with ecological requirements, pest and diseases information as well as crop field observation to produce meaningful information. Rule based systems have been proposed for processing such information as reported in Okinyokun and Anyiam [2001].

3.0 Methodology

In order to understand the underlying issues, the methodology for the research involved a survey before the model design phase. The survey was conducted to reveal the meteorological, ecological, crop health and field information needs for farmers. It was also meant to study the most suitable way of processing the available data and disseminating knowledge to small scale farmers and the most

suitable model that would be necessary to implement the processes. The research was divided into survey and data analysis phase, design and implementation phase and prototype evaluation phase. These together with the results are described here below.

3.1 Field Survey

Purposive sampling method was used in picking up the district where this research was done. The district selected was a convenient sample intended to represent a broad range of small scale farmers in Kenya. Simple random sampling technique was used in picking out the respondents during the survey. Structured questionnaire was developed and pre-tested on twenty respondents. The questionnaire was then modified prior to distribution. Fifty respondents were identified during a parents' day in a school in Kiambu district of central Kenya. All the respondents were small scale farmers. The sample was convenient because it represented farmers from all areas of the district. Each questionnaire returned was re-checked and when information was incomplete, attempts were made to trace the respondents who had filled it to request completion. The researchers also observed the actual procedure of data collection, processing, storage and dissemination of weather information to consumers at one location being served by a particular weather station, the Kabete meteorological station. Interview questions were used for three categories of respondents namely small scale farmers, meteorologists and agricultural extension officers. Face to face interviews were conducted to get the views of six meteorological officers at the meteorological station. Six agricultural officers at the crop field stations were also interviewed to know data collection, processing and dissemination methods. Documents and tools used for data collection, recording, storage and processing were collected from the meteorological station, a university campus Crop Research station and the national agricultural research institute, Kenya Agricultural Research Institute (KARI). These assisted in knowing sources of information as well as storage and dissemination methods.

## 3.2 Survey Results and Analysis

From the field survey, majority of the farmers preferred using weather information for planning planting and cultivation activities. This represented over 50% of the respondents as shown in figure 1.1 A below. 27% preferred receiving weather information through radio compared with 17% SMS as shown in figure 1.1 B below. However, respondents showed reservations with radio because bulletins are done at specific hours when probably the user is not available. This hinders free access to information when needed.

**Fig 1.1: Usage of information (fig. A) and preferred communication methods
(fig. B)**

A

B
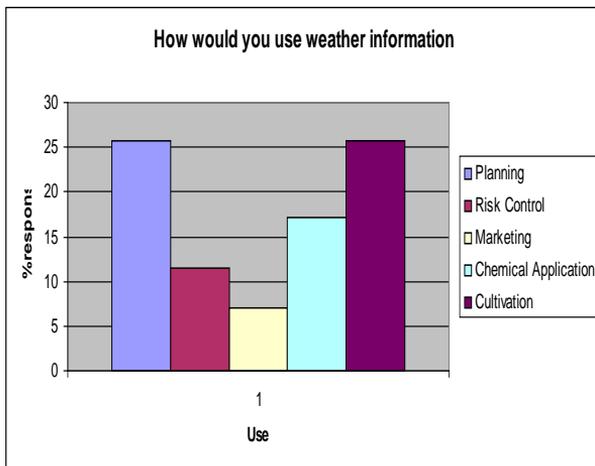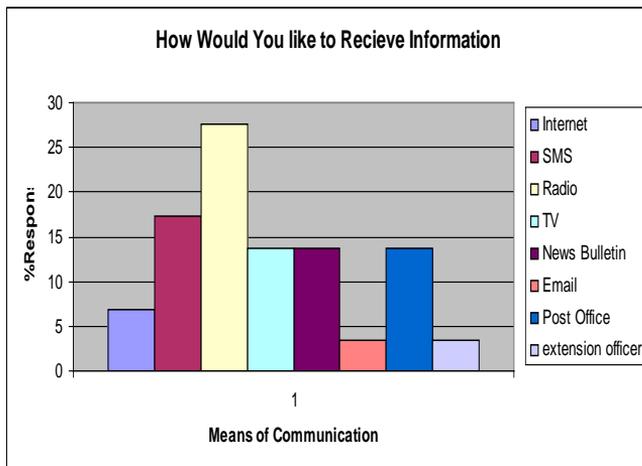
From the above results, one can see that farmers need timely information to
make various decisions such as planning for planting, cultivation and chemical
application. A good number of respondents appreciate the use of the mobile phone
for receiving information. This gives a good motivation for the use of mobile
phones in the model.

From Fig 1.2 A below, 67% of respondents claimed weather information was
completely not available. From fig 1.2 B below 28% lacked ability to interpret

weather information, 21 % of the respondents claimed weather information was not reliable.

Fig 1.2: Information Availability (fig. A) and problems encountered in using information (fig. B)

A

B
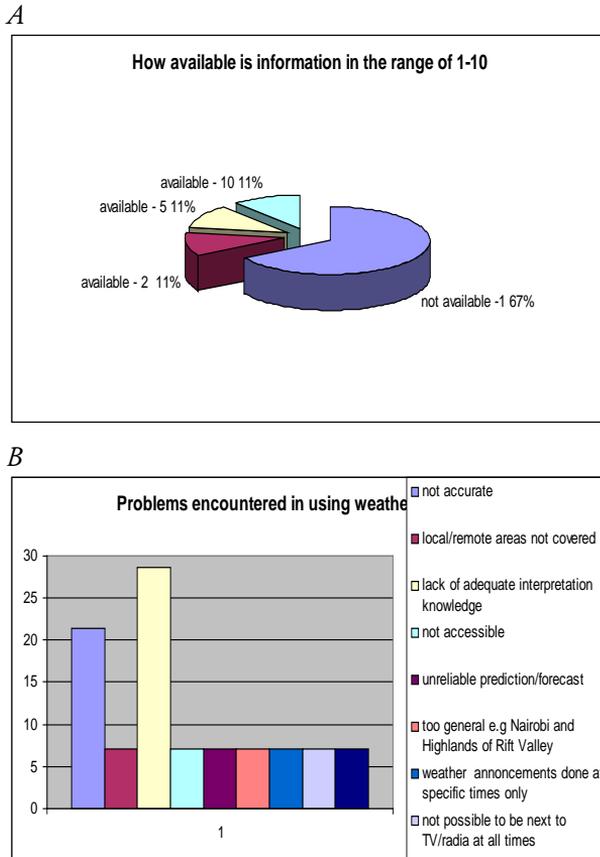
From the above results, it can be observed that information is not readily available and even in cases where it is available, it is perceived to be not accurate. Farmers cannot easily relate the given weather information and planning of the various cultivation activities. This gives the impetus for the design of an expert system with reasoning capabilities. It is also important to give the farmers control of interaction with information sources so that they can perceive better availability of information. In order to increase the perception of accuracy, it would be important to include an explanation element to such an expert system.

From fig 1.3 A below, 28% of respondents preferred regular visits by agricultural extension officers while 14% recommended clear information. The questionnaires also revealed that the agricultural extension officers were hardly available. From fig 1.3 B below, 30% of respondents wanted advisory system to help in weather forecast while 15% preferred news update.

Fig. 1.3: Suggested solutions (fig. A) and what they would like the system to do (fig. B)

A

B
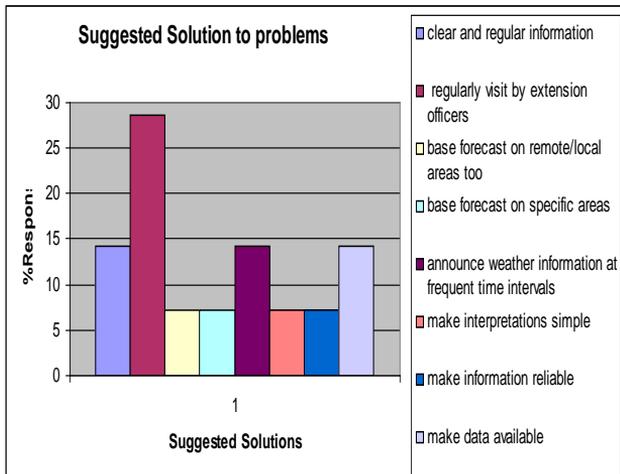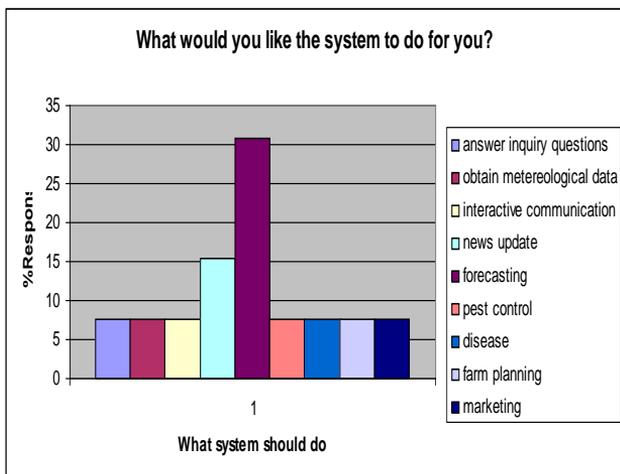
From the above results, it can be observed that there is need to supplement the services offered by the agricultural extension officers. In general it can be conclude that an expert system incorporating agricultural and weather related data would be a suitable solution.

4.0 Model Design

From documents collected from the field and interviews with experts, rules were coded and formed the inference engine of the expert system. A ruled based system is usually preferred because of ease of understanding and interpretation [Okinyokun and Anyiam 2001]. The rules were grouped in four categories namely crop suitability, pest/disease forecast, yield prediction and advance warning. An example of the type of rules used in all categories is as shown below.

Example of Yield prediction rule

IF crop STATE is POOR and crop STAGE IS EMERGENCE and effects is INSUFFICIENT RAIN   and Temperature > OPTIMUM and rainfall < OPTIMUM

Then yield is LOW

This rule shows that the yield is low if majority of reported observations by farmers, agricultural extension officers and meteorologists in the field show that the crop state is poor and crops are at emergence stage and there is insufficient rain and temperature is above crop optimum temperature and the rainfall is below optimum. All the other rules for advance warning and pest/disease forecast follow a similar pattern.

Relational Database approach was used to design the knowledge base. A similar approach was used by Okinyokun, and Anyiam [2001] to design a prototype of knowledge base system for weather monitoring and forecasting with satisfactory results. The model developed here envisages the use of two relational databases and a knowledge base. The databases would simulate the weather and agricultural research databases as currently in use by the respective institutions. The knowledge base contains crop specific information and ecological requirements. It also contains knowledge about pests and diseases. Data is entered in the knowledge base through a web based interface and text messaging using a mobile phone (SMS). Short message is convenient for small scale farmers who cannot access internet facilities. A web based interface where a user could login and post weather and crop data was used. Web technology has been proposed by Maracchi et al. [2002] in designing an internet application for agro--meteorological products in Europe. The same approach has been used by Kurnik and Susnik [2006] to come up with Slovenian agro-meteorological information system (SAgMIS). Dissemination is achieved through mobile phone and internet. As shown by the survey and analysis shown above, mobile phone would be a preferred means of information dissemination. The web interface also enables widely distributed meteorologists to login and post observations.

The Model for the Agro-meteorological System

The above design considerations and conclusions from the survey if put in context would yield to the model shown in figure 2 here below.

Fig.2:   Architecture of the Model

AGRO-ADVICE KBS SYSTEM ARCHITECTURE
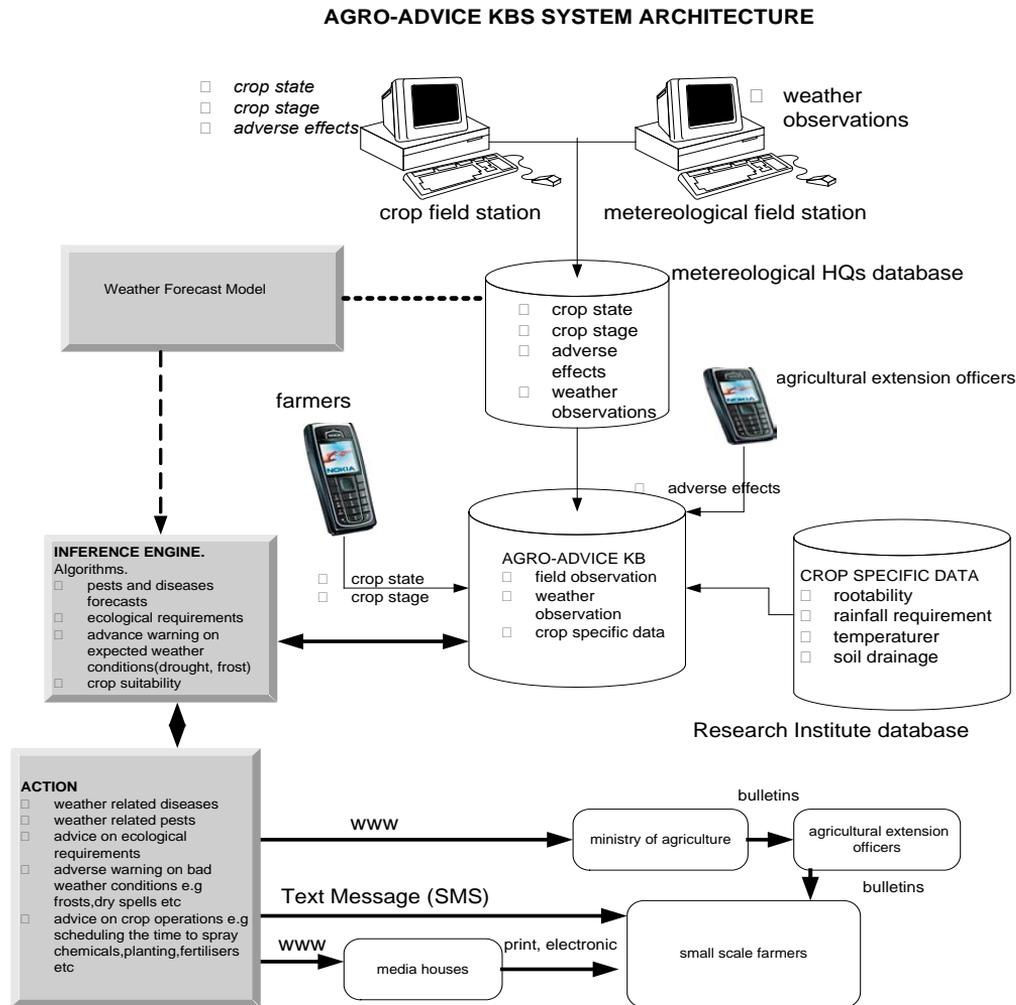
The above model shows the flow of information from various sources such as the farmers, the agricultural research institutes, meteorological stations and agricultural extension officers. The knowledge from these sources is brought together in the Knowledge Base (KB). This is then processed by the inference engine with some the algorithms as shown in the diagram. The system can perform various actions as shown. Small scale farmers can then interact with the system through short message services (SMS). The farmers can also obtain information through

mass media. The government through respective department can also obtain the information through the internet. This enables the department to produce the necessary bulletins.

Implementation of the Model

Microsoft SQL 2005 was used for implementation of the storage component of the knowledge base. Two databases were created mainly the meteorological and agricultural research institute databases. Storage tables were created in each database and relationships established. The tool was preferred because it had appropriate features for relational database development including security and relationship facilities. A combination of PHP and HTML programming languages were used to implement the inference engine, SMS modules and user interface. Codes for inference engine rules were written using PHP. SMS scripts were also implemented using PHP. Data entry forms were implemented using PHP. The two applications were platform independent and therefore the most suitable for the model. The web based interface could allow users to login and post, edit and if permission allowed edit records in the database. On the same note, small scale farmers with little computer literacy could query the system through mobile phones. Ozeki SMS server manager was used as an interface between the inference engine and the knowledge base through storage of incoming and outgoing messages. This was a messaging platform that enabled access to mobile messaging services. A mobile phone was attached to a computer where the system was hosted to act as a gateway. Users could query by sending the messages to the gateway phone which in turn could query the knowledge base and reply by sending back the results

The prototype

The prototype has a web and SMS user interface component. Web components can be used by meteorologist and agricultural research specialists

Fig 2: The Interface used by Meteorologist
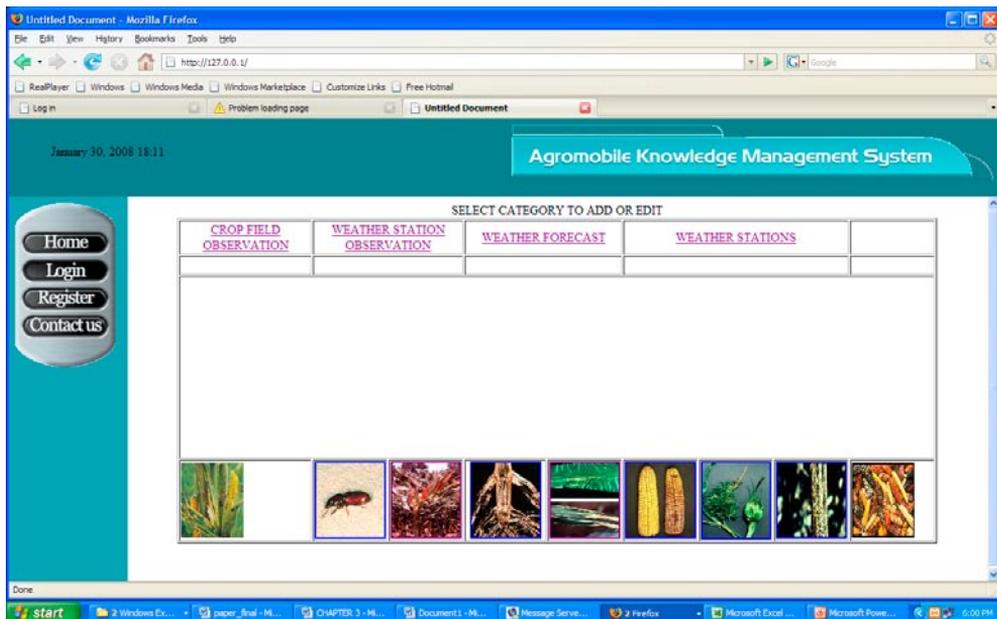
Meteorologist can login and post crop weather station data like temperature, rainfall, humidity, wind speed and sunshine. Users can also add crop field observation like crop state, stage and adverse effects. Meteorologists can also add weather forecast data. Meteorologist can also add weather station information like location, altitude, latitude, longitude and station type. For this research, SQL 2005 database was used for storage. It was preferred because it has good data manipulation mechanisms. HTML was used to implement the user interface. It was chosen because it easily implements internet applications and can be interfaced with SQL with ease. PHP was used for implementing the algorithms and other reasoning procedures and the module developed acted as the inference component of the system. PHP interfaces easily with HTML and SQL and therefore the reason for its choice. The Knowledge Base was implemented in PHP as a rule based system.

Evaluation of the Model

The goal of evaluation was to assess quality of information given by the expert system. Two simple experiments were carried out. The first was for assessing the quality of advice on crop suitability given certain climatic and ecological conditions. The second set of experiment was for predicting crop yield given some input conditions such as soil type and condition. The quality is bench marked against a human expert's response, in this case agricultural extension officer, given the same input data.

a) Crop Suitability Test

Six sets of past weather observation were entered into the system using the mobile interface. The results are summarized in table 1 here below.

Table 1: crop suitability evaluation results

Data set	System response	Agricultural Expert Knowledge	test
Set 1	suitable	suitable	true
Set 2	suitable	Not suitable	false
Set 3	suitable	suitable	true
Set 4	suitable	suitable	true
Set 5	Not suitable	suitable	false
Set 6	Not suitable	Not suitable	true

Four out of six trials representing 66% of the tests yielded outputs that agreed with the human expert. This result shows a perceived accuracy level that is satisfactory. The actual accuracy level may be measured by planting the actual crops and determining how well the plants perform. If assumed that the two accuracy levels are insignificantly the same, then we can conclude a high level of performance.

b) Yield predictions test

Eleven sets of past crop field observation data were entered into the system. For each set, a yield prediction query was sent through mobile phone interface and results compared with expert prediction. Results are summarized in the table 2 here below.

Table 2: Yield prediction evaluation results

Data set	crop	Expected yield by agro-meteorologists	Expected yield by the system	test
Set 1	maize	high	high	true
Set 2	maize	Moderate	moderate	true
Set 3	maize	Moderate	moderate	true
Set 4	maize	Moderate	moderate	true
Set 5	maize	Moderate	moderate	true
Set 6	maize	High	moderate	true
Set 7	maize	Moderate	moderate	false
Set 8	maize	High	moderate	true
Set 9	maize	Moderate	high	false
Set 10	maize	High	true	false
Set 11	maize	Moderate	moderate	true

Eight out of eleven trials were true meaning that they tallied with the expected results from a human expert. This showed that the system has perceived accuracy level of 72%. From the results presented in Fig. 1.1 28 respondents out of a total

50 (representing 56%) indicated that the information they got was not accurate or unreliable. This shows an accuracy level of only 44%. The system has a mean accuracy level of 69% based on the two sets of experiments. This is an improvement and indicates that it's a worthwhile exercise to implement the actual system.

Conclusion

This paper has demonstrated a model that can be used to implement an agro-meteorological system that can assist farmers to obtain timely information. The information is useful in planning various farming activities. We have demonstrated how communication issues can be handled between government agencies knowledge bases, field officers in agriculture and meteorology departments and small scale farmers whose computer literacy level is assumed low. Knowledge contained in agro- meteorological repositories is difficult to interpret especially for small scale farmers. This paper has demonstrated how Expert Systems can overcome these challenges.

The paper has demonstrated a prototype that is suitable for capturing, organizing, processing and disseminating knowledge to small scale farmers, government departments and media houses. The prototype demonstrated how expert knowledge can be formulated and implemented in the form of rules to provide reasoning mechanism for yield prediction, crop suitability check, pest and disease prediction as well as scheduled warning based on weather condition. Through evaluation tests conducted on the prototype, it was showed that a system developed out of the designed model would enjoy better accuracy levels of up to 69% as opposed to 44% experienced by current means of processing and dissemination.

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