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A CommonKADS Model Framework for Web Based Agricultural Decision Support System

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ABSTRACT

Increased demand of farm products and depletion of natural resources compel the agriculture community to increase the use of Information and Communication Technology (ICT) in various farming processes. Agricultural Decision Support Systems (DSS) proved useful in this regard. The majority of available Agricultural DSSs are either crop or task specific. Less emphasis has been placed on the development of comprehensive DSS, which are non-specific regarding crops or farming processes. The crop or task specific DSSs are mainly developed with rule based or knowledge transfer based approaches. The DSSs based on these methodologies lack the ability for scaling up and generalization. The Knowledge engineering modeling approach is more suitable for the development of large and generalized DSS. Unfortunately the model based knowledge engineering approach is not much exploited for the development of Agricultural DSS. CommonKADS is one of the popular modeling frameworks used for the development of Knowledge Based System (KBS). The paper presents the organization, agent, task, communication, knowledge and design models based on the CommonKADS approach for the development of scalable Agricultural DSS. A specific web based DSS application is used for demonstrating the multi agent CommonKADS modeling approach. The system offers decision support for irrigation scheduling and weather based disease forecasting for the popular crops of India. The proposed framework along with the required expert knowledge, provides a platform on which the larger DSS can be built for any crop at a given location.

Keywords. Agricultural decision support system, CommonKADS, irrigation scheduling, disease forecasting, India

1 Introduction

The increased demand for farm products and the quality of products along with the depletion of precious natural resources made the use of Information and Communication Technology (ICT) in agricultural processes inevitable. Agriculture emerged as one of the potential areas of ICT application and hence ICT in agriculture became a very important interdisciplinary research topic in recent past. It broadly covers major processes of agriculture like irrigation scheduling (Alminana et al., 2010), nutrient management (Zhu et al., 2001; Papadopoulos et al., 2011), disease forecasting (Wee Soo Kang, 2010), climate forecasting (Fraisse et al., 2006), food transportation and tracking (Verdouw et al., 2013), etc. Agricultural systems are often complex and semi-structured which makes Decision Support Systems (DSS) helpful tools for the agricultural community (Eom and Kim, 2005). Agricultural DSS include computer based solutions for managing one or more spatial and temporal variability aspects associated with agricultural systems. One of their aims is to improve productivity and profitability of agricultural systems in spite of differences in variability (Pierce and Nowak, 1999; Naiqian Zhang, 2002; Perini & Susi, 2003; Garretta et al., 2012). They may also provide support in conserving natural resources by optimizing their use and in moving towards sustainable agricultural systems. In research literature, DSS in general are broadly categorized as Decision Support Systems (DSS) in a narrow sense, as Expert Systems (ES), as Knowledge based or

Intelligent DSS (IDSS), and as Web based DSS (Manos, et al., 2004).

In this context, DSS in a narrow sense support in making decisions with the help of available data (or information) and domain knowledge for unstructured and semi-structured problems (Ford, 1985). ES aims to achieving better system performance with the involvement of a computer program which mirrors the decision behavior of an expert person. Although there is no specific depiction for IDSS and Web based DSS, they can be interpreted as a hybrid system of DSS and ES. The roles of these systems are mainly diagnostic, advisory, informative and operational. Application areas encompass wide-ranging activities of agriculture such as irrigation scheduling, farm management, disease identification, disease forecasting and nutrition advisory (De and Bezuglov, 2006; Singh et al., 2008; Magarey et al., 2007). Better accessibility of internet among farmer communities made it possible to focus on web based agricultural DSS. In the recent past, several research publications demonstrate growing interest in this type of decision support systems (Saini et al., 2002; Leib et al., 2001).

The development of Agricultural DSS is quite established and offers a wide variety of support systems. Detailed discussions of various crop specific management systems like EPIC (Maize and Cowpeas), Glycim (Soybean), FASSET (Wheat), AGDSSP (Sugarcane), HADSS (Wheat), etc. are well presented in Antonopoulou, et al. (2010). These types of DSS mainly offer decision support exclusively for a specific crop concerned. Climate forecast information systems like 'AgClimate' provide prior information about the weather to mitigate climate variability issues (Fraisse et al., 2006). Literature involves many process-specific Agricultural DSS for irrigation scheduling, nutrition management, and pest management (Leibet al., 2001; Alminana et al., 2010; Steele et al., 2010). In summary, one can state that the majority of existing Agricultural DSS is either crop or task specific and the development approach considered in such Agricultural DSS is either rule based or based on knowledge transfer.

In the late nineties, the Knowledge Based Systems (KBS) became very popular in almost all spheres of life. However, according to literature, efforts for transferring such system concepts into large systems for practical use are limited. One of the bottlenecks of converting a rule based or knowledge transfer based KBS into a large generalized system is the lack of scalability. This has generated a need for a more systematic approach in the development process of KBS as proposed by the concept of Knowledge Engineering (KE). The core of knowledge engineering or modeling is to represent an expert system as an implementation-independent model of competence. It represents the structure of the system prior to its implementation in a particular tool (Motta, 2001). The modeling approach to construct Knowledge Based Systems (KBS) was well received among the Knowledge Engineering (KE) communities due to its modular structure and its ability to break down the knowledge engineering problem into smaller tasks. Unfortunately, a survey on expert systems revealed that the model based knowledge engineering approach is not much utilized in the development of Agricultural DSS (Liao, 2004).

The primary objective of this paper is to present a development framework for Agricultural DSS based on the concept of knowledge engineering. There are many modeling frameworks proposed and subsequently used by the KE communities. This paper does focus on one of the most popular modeling frameworks, CommonKADS. In the following sections, the paper first introduces into the CommonKADS framework for the development of scalable Agricultural DSS for broad and practical use. This is followed by an outline the framework's integrated models focusing on organization, agents, tasks, communication, and knowledge and design using a selected example DSS. The last section presents a comparative analysis of the usability of the proposed modeling framework as compared with other approaches and concludes with a discussion of future developmental aspects.

2 CommonKADS Modeling Framework

The knowledge engineering modeling approach simplifies the process of KBS development by breaking down the whole problem into smaller tasks. These tasks are known as models. The models help to select and configure the reusable components for a specific application. There are many modeling frameworks proposed and subsequently used by the KE communities such as CommonKADS, MIKE, PROTAGE-II, VITAL, Commet and EXPECT (Studeret al., 1998). The CommonKADS framework proposes six models in the construction process of KBS. They focus on organization, agents, tasks, communication, knowledge and design (Scet al., 1994). For a more detailed discussion of the framework the paper does focus on the development of a generalized Agricultural DSS aimed at providing decision support on optimizing irrigation scheduling depending on weather based forecasting of the occurrence of plant diseases. The selected example allows to discuss the generalized framework and to demonstrate its generic use.

2.1 Organization Model

The first model within the framework provides the organizational structure for the problem under investigation. The important actors, their roles and major functions are presented in this model. For the proposed Agricultural DSS, the major actors are knowledge providers (agricultural scientist, geologist and microbiologist), knowledge engineers/managers, knowledge system developers and knowledge users (farmers). Figure 1 shows the organization model of the web based Agricultural DSS with the roles and functions of each actor. The knowledge providers are traditional experts of the domain. The knowledge engineer elicits the domain knowledge from the knowledge providers. More details on these processes are provided later in the respective section. Knowledge system developers employ the knowledge system using a suitable software platform. Sometimes this role is played by the knowledge engineer also. Finally, the farmers are the end user of the knowledge. The final form of the knowledge must be in usable form and must be helpful to the end user.

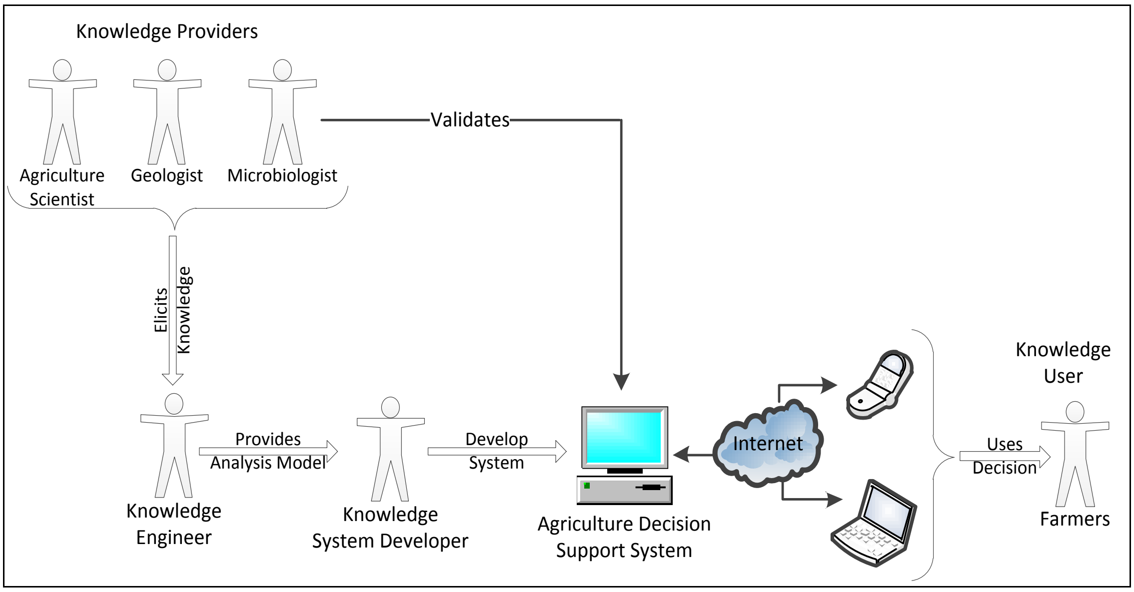


Figure 1. Organization model of a web based agricultural decision support system

2.2 Task Model

In the CommonKADS framework, the entire problem is broken down into smaller tasks. Each task represents a separate function expected from the DSS. The task model deals with required inputs, information processing, knowledge preconditions and expected output from each task. In general, the task model offers an in depth task analysis for the identified processes. The example agricultural DSS involves two processes, irrigation scheduling and disease forecasting.

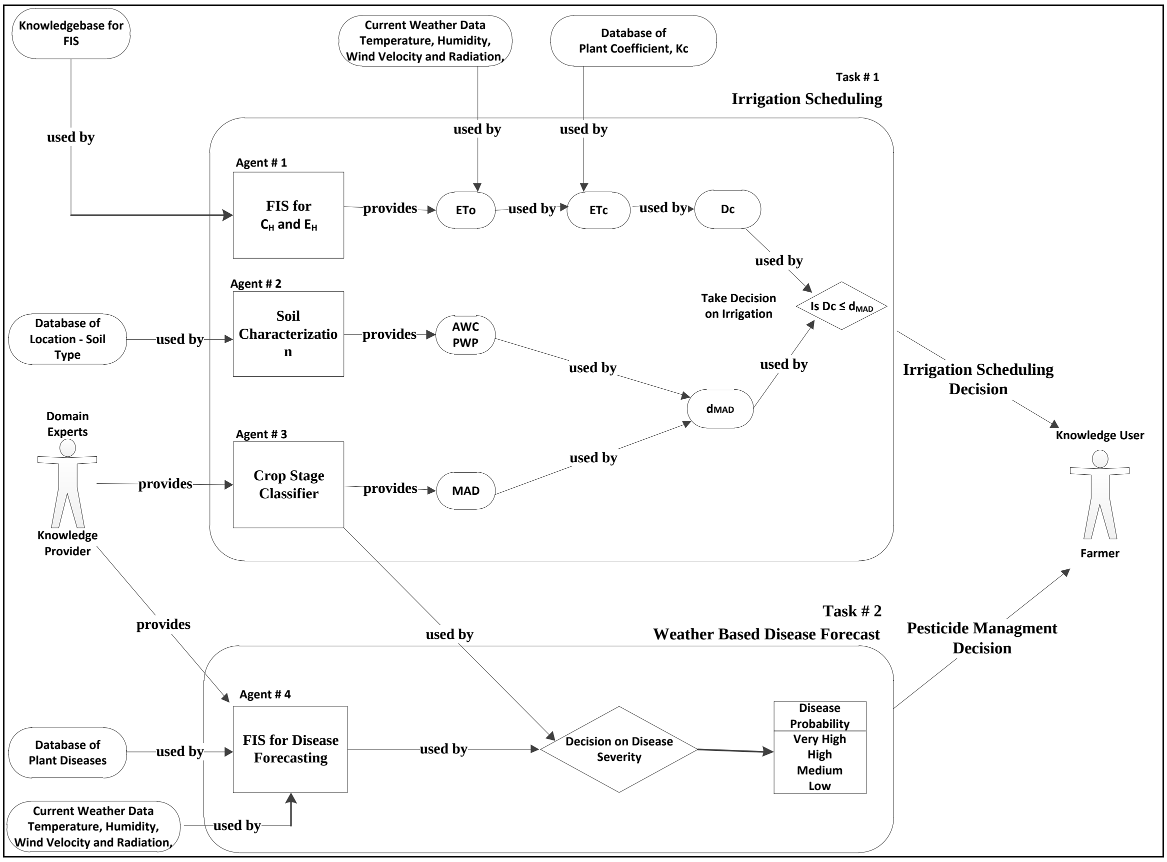
For irrigation scheduling, literature proposes three major approaches. These are soil moisture based, plant based, and weather based (Andales et al., 2011; Dukes and Scholberg, 2005; Goldhamer and Fereres, 2004; Sharon and Bravdo, 2000). Unlike the soil moisture based and plant based methods, the weather based method does not require costly and specific sensors for the measurement of soil moisture, canopy temperature and leaf thickness. It is more realistic to use this method for irrigation scheduling than the others. For this task the static inputs are the type of soil, type of crop, development stages (for root zone information) and crop co-efficient values, K_c. It also needs dynamic data like the current values of temperature, wind velocity and humidity. Weather based disease forecasting is a useful tool to protect crops from losses due to pest and diseases (Magarey et al., 2007; Soon Sung Hong et al., 2010).

The second task is to suggest to farmers the probability of occurrence of a specific disease at a given point of time. This task needs the dynamic inputs mentioned in the first task. A huge knowledge base of various pathogens and their favorable climate conditions are required to complete this task.

2.3 Agent Model

The task model clarifies what is required to be done to perform the task. Each task could be carried out by one or more agents. The term agent is used in a general sense. It could be a human, a computer program or some intelligent machine. As shown in figure 2, the first task needs three agents and the second needs one agent.

An accurate estimation of Evapotranspiration (ET_o) is very important for the implementation of weather based irrigation scheduling. A Fuzzy Inference System (FIS) system is used for the adjustment of the Hargreaves equation (for accurate estimation of ET_o) parameter (Patel et al., 2012). Agent # 1 provides these values. Soil characteristics like Available Water Content (AWP) and Permanent Wilting Point (PWP) are very significant for irrigation scheduling. Agent # 2 provides these data from the soil database, which is created from the knowledge of the geologist.



(AWC = Available Water Content in mm, PWP = Permanent Wilting Point in mm, C_H and E_H = Co-efficient for the Hargreaves equation for ET_0, K_c = Plant Co-efficient, ET_c = Plant Evapotranspiration in mm/day, MAD= Management Allowable Depletion in %, FIS = Fuzzy Inference System)

Figure 2. Agent, task and communication model of the agricultural decision support system

The third agent provides the information related to the crop stage and root zone depth. Agent # 4 inferences the probability of disease occurrence with the help of weather and crop related data.

2.4 Communication Model

In a multi agent system, the communication between the agents is an important part. The communication model structures the dialogue between agents. It specifies the details of the information exchanges between the agents. In the proposed case, agent # 4 needs the data from agent #3 to complete the second task of disease forecasting. Similarly, the agents get the information from the database or the knowledgebase. Agent #1 and agent #2 take the information from the knowledgebase and database. The communication model presents the flow of information among the agents as well as with the external information sources. It also covers the information exchange specifications like provide, used by, elicits, requests, offers, etc. Figure 2 depicts the communication structure of the proposed DSS.

2.5 Knowledge Model

The knowledge model is an important aspect in the CommonKADS framework. There are several advantages of knowledge acquisition through a modeling paradigm. In a conventional rule based KBS development there is a knowledge acquisition bottleneck as the development of the system is more depend on the expert. The main difficulty of a rule based approach is the knowledge elicitation from the experts and its transfer into the system. A knowledge model provides a knowledge-centric view. It specifies the type of knowledge required to complete the task. The model is used as knowledge elicitation tool for the knowledge engineer. Careful design of the knowledge model speeds up the process of knowledge acquisition. It is an important approach for creating more generalized KBS.

To implement an irrigation scheduling task, several details about the crop and soil are required. These can be collected from the domain experts in the form shown in Table 1. The challenge in designing the knowledge model is to prepare the details of expected information from the experts. The disease forecasting task needs the knowledge from the microbiologist and agriculture scientist. The proposed knowledge elicitation form for this is shown in Table 2.

2.6 Design Model

This model suggests the tools for transferring the concept into implementation. It specifies the required hardware and software platform. The details about the functional and technical specifications of various modules are provided in this model. In the example case, open source platforms like Android and Java are selected for the implementation of web based solutions. To improve the accessibility of the DSS among the farmers' community, the model proposes the use of mobile devices.

Table 1. Knowledge elicitation form for irrigation scheduling of cotton crops

Crop Name	**:** Cotton (Gossypium)		
Variety	: H8, H10		
Preferred Month of Sowing	: July - August		
Best Suitable Type of Soil	: Black		
Suitable pH level	: 6 to 7.5		
Plant Days	: 160 to 180		
Stages	**Number of Days**	**Root Zone Depth, cms**	**Plant Coefficient, Kc**
Initial:	0 to 45	: 10	: 0.35
Development:	46 to 85	: 11 to 25	: 0.35-1.20
Mid Season:	86 to 110	: 26 to 40	: 1.20
Late Season:	111 and above	: 40	: 1.20-0.5
Stages	**Best Temperature Range °C (Day Temp)**	**Best Humidity %RH**	**% Management Allowable Depletion (MAD)**
Initial:	28 to 30	: Any percentage	: 55
Development:	30-32	: < 60 %	: 55
Mid Season:	30-35	: < 25 %	: 65
Late Season:	35-38	: < 17 %	: 75

Table 2. Knowledge elicitation form for disease forecasting of corn crop

Pathogen and Disease	Susceptible Stage	Days after sowing	Maximum Safe Day Temp °C	Minimum Safe Day Temp °C	Maximum Humidity %RH	Leaf Wetness Duration Hrs
Pathogen Fungus *Puccinia Sorghi* (Common rust)	Development Stage	45 to 80 Days	25-28	10-12	80-90	6 Hrs

3 Discussion and Conclusion

Agricultural systems are quite complex and only partly known. As a consequence, the design of Agricultural DSS is quite challenging. Traditional 'knowledge transfer approach' based development processes convert knowledge of an expert directly into the code of DSS. In such an approach information about the interconnections of the information within the system can rarely be revealed. So the updating of the knowledge would be difficult. The KE concept utilized a.o. in the CommonKADS model approach provides a modular and scalable framework which is needed to construct multi-tasking and generalized (e.g. not crop specific) DSS.

In this framework, the entire problem can be broken down into the smaller parts designated as models dealing with organization, agents, tasks, communication, and knowledge and design. The organization model provides an overview of the problem and the role of various actors in the DSS. Details of the task strategy are captured in the task and agent model. The knowledge model includes the knowledge elicitation form. The complexity of the forms is kept at a level which serves the purpose without creating any unnecessary hassles to knowledge providers. Careful designing of the knowledge model ensures the streamline flow of knowledge into the system. The hardware and software requirement are defined in the design model.

The proposed framework provides a more general view on the Agricultural DSS problem. The modelling framework allows to develop a comprehensive (not crop or task specific) decision support system.

The utilization of the model approach helps to remove the bottleneck of knowledge acquisition that occurs in the so called knowledge transfer approach. Typically, the knowledge modeling approach encourages the reuse of knowledge in Agricultural DSS development. In the example scenario utilized in the paper, the Agricultural DSSs are either crop or task specific. This specification has been introduced as the development of these systems is usually linked with a conventional rule based or knowledge transfer approach. An increased use of the model based approach in the development of Agricultural DSS would certainly push the development of DSS in general and also of DSS with a more comprehensive view. Furthermore, it has an advantage over the conventional knowledge transfer approach in terms of scalability and modularity.

References

Andales, A.A., Chávez, J. L., and Bauder, T. A. (2011). *Irrigation Scheduling:The Water Balance Approach.* Colorado: Colorado State University.

Alminana, M., Escudero, L. F., Landete, M., Monge, J. F., A.Rabasa, and Sanchez-Soriano, J. (2010). WISCHE: ADSS for water irrigation scheduling. *Omega, **38***: 492–500.

Antonopoulou, E., Karetsos, S., Maliappis, M., and Sideridis, A. (2010). Web and mobile technologies in a prototype DSS for major field crops. *Computers and Electronics in Agriculture, **70**:* 292–301.

Steele, D.D., Scherer, T.F., Hopkins, D.G., Tuscherer, S., and Wright, J. (2010). Spreadsheet Implementation of Irrigation Scheduling by the Checkbook Method for North Dakota and Minnesota. *Applied Engineering in Agriculture, **26***(6): 983-995.

De, S., Bezuglov, A. (2006). Data model for a decision support in comprehensive nutrient management in the United States. *Environmental Modelling and Software, **21***: 852-867.

Dukes, M. D., Scholberg, J. M. (2005). Soil Moisture Controlled Subsurface Drip Irrigation on Sandy Soils. *Applied Engineering in Agriculture*: 89−101.

Eom, S., Kim, E. (2005). A survey of decision support system applications (1995–2001). *Journal of the Operational Research Society, December*: 1-15.

Ford, F. N. (1985). Decision support systems and expert systems: A comparison. *Information & Management*: 21-26.

Fraisse, C., Breuer, N., Zierden, D., Bellowc, J., Pazd, J., Cabrera, V., et al. (2006). AgClimate: A climate forecast information system for agricultural risk management in the southeastern USA. *Computers and Electronics in Agriculture, **53***: 13–27.

Garretta, K. A., Dobsonb, D. M., Kroschelc, J., Natarajan, B., Orlandinie, S., Tonnangc, H. E., et al. (2012). The effects of climate variability and the color of weather time series on agricultural diseases and pests, and on decisions for their management. *Agricultural and Forest Meteorology*.

Goldhamer, D. A., Fereres, E. (2004). Irrigation scheduling of almond trees with trunk diameter sensors. *Irrigation Science, **23***: 11-19.

Leib, B. G., Todd, V. E., and Gary, M. (2001). WISE: a web-linked and producer oriented program for irrigation scheduling. *Computers and Electronics in Agriculture, **33:*** 1-6.

Liao, S. H. (2004). Expert system methodologies and applications—a decade review from 1995 to 2004. *Expert Systems with Applications*: 1–11.

Magarey, R. D., Borchert, G. A., Fowler M., D., Sutton, T. B., Colunga-Garcia, M., and Simpson, J. A. (2007). NAPPFAST: An Internet System for the Weather-Based Mapping of Plant Pathogens. *Plant Disease*, Vol. **91** No. 4: 336-345.

Manos, B., Ciani, A., Bournaris, T., Vassiliadon, I., and Papathanasious, J. (2004, August). A taxonomy survey of decision support sysems in agriculutre. *Agriculture Economics Review,*Vol. **5** (2): 80-93.

Motta, E. (2001). The Knowledge Modelling Paradigm. In S. K. Chang, *Handbook of Software Engineering and Knowledge Engineering* (pp. 1-29). Singapore: World Scientific Publishing.

Naiqian Zhang, N. W. (2002,). Precision Agriculture- a wordwide overview. *Computers and Electronics in Agriculture, **36***(2-3): 113-132.

Papadopoulos, A., Kalivas, D., and Hatzichristos, T. (2011). Decision support system for nitrogen fertilization using fuzzy theory. *Computers and Electronics in Agriculture*, vol.**78**: 130-139.

Patel, J., Patel, H., and Bhatt, C. (2012). Fuzzy Logic based Decision Support System Framework for Irrigation Schduling. *NUiCONE.* Ahmedabad: Nirma University.

Perini, A., Susi, A. (2003, January). Developing a Decision Support System for Integrated Production in Agriculture. *Environmental Modelling and Software*: 1-16.

Pierce, F. J., Nowak, P. (1999). Aspects of Precision Agriculture. *Advances in Agronomy, **67:*** 1-65.

Saini, H. S., Kamal, R., and Sharma, A.N. (2002). Web Based Fuzzy Expert system for Integrated Pest Management in Soybean. *International Journal of Information Technology*, Vol.**8**: 55-74.

Schreiber, A., Wielinga, B., Hoog, R. D., Akkermans, H., and Veld, W. V. (1994). CommonKADS: A comprehensive methodology for KBS development. *IEEE Expert, December*: 28-37.

Sharon, Y., Bravdo, B. (2000). Automated Orchad Irrigation based on Monitoring Tugor Potential with leaf sensor. *International Water and Irrigation Review*: 14-19.

Singh, A. K., Tripathy, R., and Chopra, U. K. (2008, July). Evaluation of CERES-Wheat and CropSyst models for water–nitrogen interactions in wheat crop. *Agricultural Water Management, Volume **95***(Issue 7).

Soon Sung Hong, Y. K., Kim, K. R., Kim, S. K., and Kang, E. W. (2010). A Web-based Information System for Plant Disease Forecast Based on Weather. *The Plant Pathology Journal, **26**(1):* 37-48.

Studer, R., Benjamins, V. R., and Fensel, D. (1998). Knowledge Engineering: Principles and methods. *Data & Knowledge Engineering, **25**:* 161-197.

Verdouw, C. N., Vucic, N., Sundmaeker, H., and Beulens, A. (2013). Future Internet as a Driver for Virtualization, Connectivity and Intelligence of Agri-Food Supply Chain Networks. *International Journal on Food System Dynamics*: 261-272.

Wee Soo Kang, S. S. (2010). A Web-based Information System for Plant Disease Forecast Based on Weather. *The Plant Pathology Journal*, **26**(1): 37-48.

Zhu, A. X., Hudson, B., Burt, J., Lubich, K., and Simonson, D. (2001). Soil Mapping Using GIS, Expert Knowledge, and Fuzzy Logic. *Soil Science Society of America Journal,* **65**: 1463–1472.