LPWM Expert: An Expert System for Water Management During Land Preparation in a Paddy Estate in Malaysia

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ABSTRACT. *Seberang Perak paddy estate, Malaysia, which practices intensive mechanized farming still uses the traditional approach in decision-making. Water management during land preparation, the critical process to be completed within scheduled duration, needs better and quick management decisions for many alternative scenarios. A method proposed to encapsulate specific knowledge available with domain experts and generated through modeling to an expert system (Land Preparation Water Management (LPWM) Expert) is outlined. The LPWM expert consists a database, a model base, a knowledge base and a user interface. Knowledge was gathered through discussions and interviews with domain experts. Collected quantitative data were used in modeling canal flows and water balance to extract knowledge for different possible scenarios. Knowledge base represents extracted knowledge as rules. All the rules in IF-THEN structure and syntax are verified with the help of wxCLIPS debugging capability. The results generated by the LPWM expert are validated with the domain experts. The expert system proposes decisions for many combinations of scenarios considering all the possible variations in rain, irrigation water supply, secondary blocks, sub-estates, cropping seasons and cropping intensity. The LPWM expert is user friendly and efficient where the outputs are supported with graphics.*

INTRODUCTION

Paddy production in Malaysia faces acute labor shortage due to availability of alternative employment in industrial sector. This has led to rationalize land ownership and size, mechanize and change objective to commercial orientation from subsistence level to decrease the dependence on labor. In early eighties, Malaysia introduced paddy estate concept similar to plantation crops. Federal Land Consolidation and Rehabilitation Authority (FELCRA), a government owned company, manages the Seberang Perak paddy estate, the biggest and oldest in Malaysia. Seberang Perak paddy estate maintains 250% cropping intensity by strict adherence to cropping schedules. The most critical operation, land preparation, needed to be completed in 14 – 16 days that depends on rainfall as canal flows are not sufficient. Delay in land preparation could affect achievement of desired cropping intensity.

Decision making needs to be shifted from traditional to a sophisticated approach that allows decision making alternatives for different scenarios. This is only possible through an expert system (ES) consisting heuristic knowledge for the problem domain. ES is an intelligent computer program with knowledge and inference procedures to solve problems that are difficult to obtain human expertise (Barr and Feigenbaum, 1982).

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Few ESs are reported for problem solving in the domain of irrigation engineering (Nevo and Amir, 1991; Srinivasan et al., 1991; Mohan and Arumugam, 1995, Linda et al., 1998; Kuo et al., 2000; Silva et al. 2001). Kuo et al. (2000) applied on-farm irrigation scheduling and genetic algorithm to optimize economic profits, simulate water demand, crop yields and area cultivated to each crop according to constraints. Linda et al. (1998) developed a decision support system (DSS) for improved irrigation practices, which considers the irrigation management plan prepared by the farmer. Srinivasan et al. (1991) developed an ES for decision-making on water management in an irrigation project, which determines the type of scheduling based on the computed water requirement, water availability data and general information about the site conditions. Mohan and Arumugam (1995) developed an ES to select suitable evapotranspiration estimation methods for southern India. Silva et al. (2001) developed a DSS to analyze and evaluate crops and cropping systems with identification of limitations. Slow emergence of ES in irrigation management is due to difficulty in collection of domain knowledge from various sources and simulation is not straight forward (Mohan and Arumugam, 1997). This paper presents a way to encapsulate specific knowledge available and generated to a land preparation water management ES (LPWM Expert) for Seberang Perak paddy estate.

MATERIALS AND METHODS

Study area

Seberang Perak paddy estate is located at 4^0 7'N and 101^0 4' E (Fig. 1). The estate has a run-of-river irrigation system fed by Perak River. Seberang Perak has a tropical climate with annual rainfall of about 2100 mm with monthly peaks in April and October. The distinct dryer seasons are from December to February and June to September.

The estate has 3630 plots summing up to an extent of 4482 ha. There are three sub-estates (E, F and G) managed by three managers who are under a regional manager. Almost all the paddy lots are uniform in shape and each lot has an extent of 1.2 ha. Each sub-estate is divided again into secondary blocks fed by a secondary canal and managed by either a senior assistant executive or an assistant executive, who are answerable to their respective manager. The Seberang Perak paddy estate management, a resource saving innovation, saves labor through overall planning of labor utilization and mechanization.

Data collection

Data needed for an ES are both qualitative (domain experts' knowledge) and quantitative (recorded or measured data for a long period of time). The quantitative data are processed, modeled, and simulated in order to generate knowledge for different scenarios. Daily values of weather data and pan evaporation data were collected from Sitiawan meteorological station for a period of 30 years (1971–2001). Daily rainfall values were collected from Ulu Dedap rain gauging station (1965–2002). Data on canal systems were collected from Department of Irrigation and Drainage (DID). These include all physical measurements of all the canals, flows, structure information and rating curves. Water level at few control structures and gates, which are measured, were also recorded. The knowledge on water management during land preparation in Seberang Perak paddy estate was gathered from domain experts such as estate managers, irrigation engineers and field staff from estate and DID through unstructured interviews or discussions, field visits, reports and documents available on management aspects in the estate.
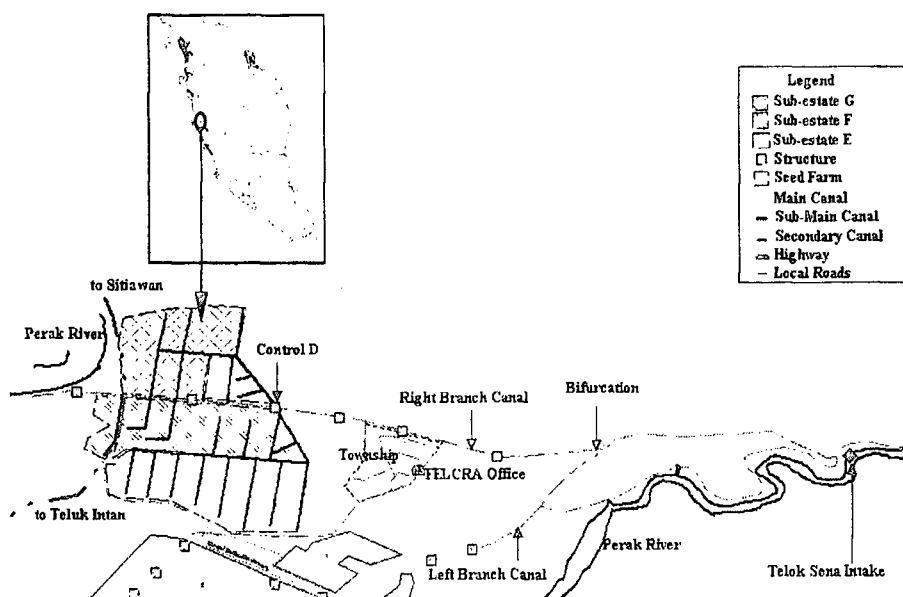
Fig 1. Seberang Perak Paddy Estate.

Modeling and knowledge extraction

Water balancing and canal simulations were used to generate knowledge related to water management during land preparation. This knowledge was then converted to rules that are the building blocks of the knowledge base of the ES. The water balance equation used in this study is

$$WD_j = WD_{j-1} + RF_j + IR_j - ET_j - SP_j - DR_j$$

where; WD_j is water ponding depth in the field (cm), WD_{j-1} is water ponding depth in the field on the (j-1)th day (cm), RF_j is rainfall received (cm), IR_j is irrigation water applied (cm), ET_j is crop evapotranspiration (cm), SP_j is seepage and percolation loss (cm) taken as 0.35 cm/day (JICA, 1998), and DR_j is drainage (cm). The term j is time period in days. Surface runoff is omitted as the plots are designed to prevent runoff. For land preparation period ET_j was replaced with pan evaporation as pan evaporation model was found to be one of the best models for the study area (Najim et al., 2003).

Canal simulations were done using CanalMan (Merkley, 1997) software that is capable of simulating hydraulic simulations of unsteady flow in branching canal networks. The CanalMan was initially validated for the study area and is given in Najim et al. (2004). The canal simulation considered all possible scenarios of water levels along main canal.

Water balance was applied for all possible scenarios including seasons and input variations to extract knowledge. Knowledge generated through canal simulation and water balance was presented to the domain experts for validity and suitability checking. Knowledge accepted by the domain experts is converted to pseudocodes and translated to rules prior to be

added to the knowledge base of LPWM Expert. Decision-making process followed by domain experts was coded and added to the inference mechanism of the ES.

Designing the ES

The designing process of the ES follows three major phases (Turban, 1995). LPWM Expert consists four components, a database, a model base, a knowledge base and a user interface and their interactions are given in Fig. 2. The databases and the model bases are external to the ES. Databases consist of historical data with extrapolation capability such as weather parameters, rainfall patterns, canal flows and evaporation data. Canal simulation model (Najim *et al.*, 2004) and water balance model are the major models that generate the required knowledge. The knowledge base, specific to the problem domain in question, consists many rules represented as IF-THEN statements. The user interface, through which the user interacts with the ES, needs facilities that allow the user to interact with minimum efforts and get outputs in a simpler and efficient way.

The ES is developed using wxCLIPS (Smart, 1997) that facilitates generating portable programs and running under a windows environment with graphic capabilities. The wxCLIPS gives an efficient graphical user interface that is suitable for interactive decision-making.

The user interface capabilities used in the ES are screens and data input facilities (input box, dialog box, button and menu facility). The user interacts with the system providing necessary inputs through these facilities. Two screens are utilized, a main frame that keeps all the user interface capabilities together as a platform and a sub-frame to output graphics.
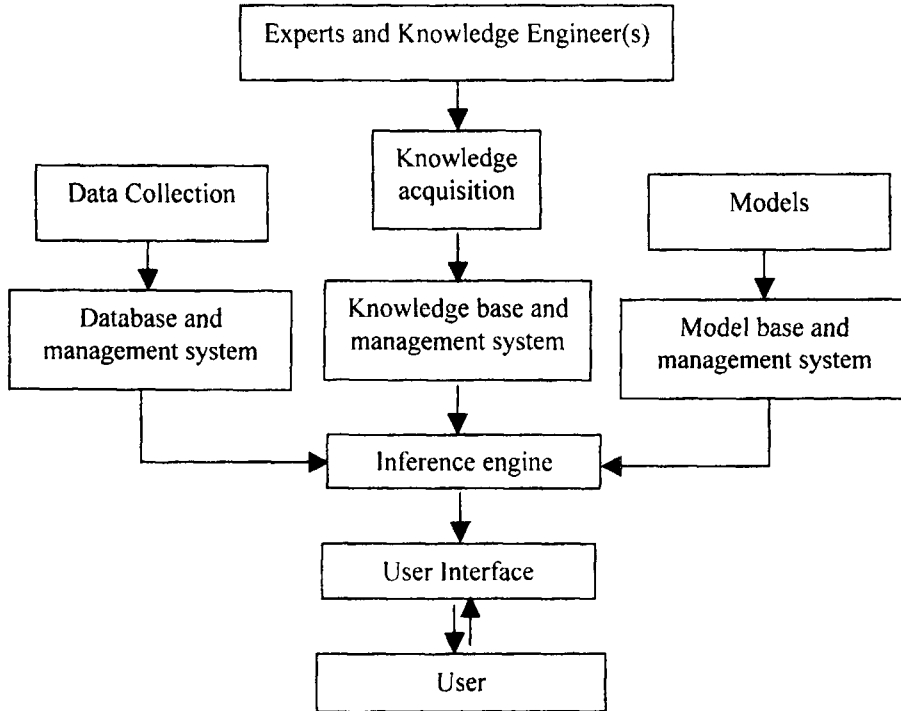

Fig 2. Expert system components and interactions.

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RESULTS AND DISCUSSION

LPWM Expert through its user interface (Fig. 3) guides the user in a clear, concise and easily understandable manner. The menu facilities provide basic information on the project area and guide the user through the ES. The menu module consists several menus with sub-menus, which transfer information efficiently. The guideline menu guides the user through all ES capabilities and output formats that facilitate efficient decision-making using the ES.

The main program module of the ES is the knowledge based land preparation water management component. Simply pressing a button will execute the knowledge-based program calling the relevant deffunction. The ES is self-explanatory and interacts with the user posing dialog boxes to select most suitable scenarios, which are needed to come up with conclusions. The inference engine, a component of wxCLIPS, traces the user choices through dialog boxes together with data inputs. The algorithm calls embedded mathematical relationships and does necessary calculations if any needed. The information on the working memory will be used by the inference engine and fires appropriate rules to display final results as decision alternatives for the user. The ES provides intermittent knowledge wherever necessary to make management issues clear to the user, which include management differences among sub-estates, design discharges along different canals, minimum possible supply durations and warnings on incorrect inputs. Outputs based on the options and inputs provided by the user are displayed on the output display modules. The user can save these results using "File" menu shown in Fig. 3.

Water management during land preparation varies among the sub-estates. Sub-estates E and F practice the same land preparation management while sub-estate G differs. The land preparation water requirement is supplied in two steps in sub-estate G while it is in one step in E and F. Land preparation water supply is dependant on cropping intensity and season, possible discharges along canals supplying a particular secondary block and the desired duration to complete the supply. When the flows are less than design discharges, the user has to specify a range of flows from the model proposed flow levels at control D.
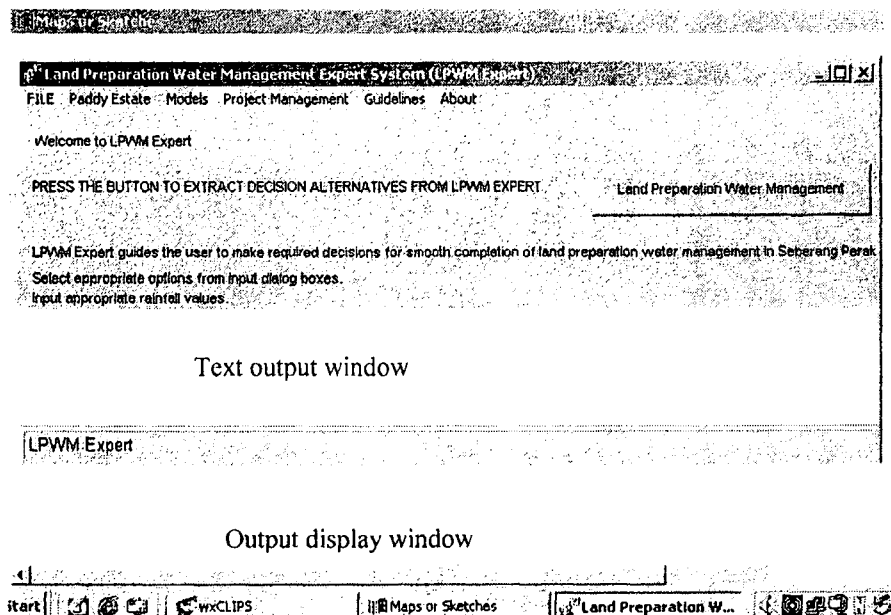

Fig 3.   User interface of LPWM Expert.

The land preparation requirement for the Seberang Perak paddy estate is 250 mm (JICA, 1998) out of which 150 mm are used for soaking and the remainder to provide required standing depth of 63.5 – 100 mm for direct seeding. The algorithm within the ES checks whether the irrigation supply and rainfall received together can supply this amount within the preferred duration. The LPWM expert will provide relevant outputs for such cases considering all the combinations of options. If the amount could not be supplied within the desired duration or the amount supplied is less than the requirement, the LPWM expert proposes other alternative solutions to complete water management during land preparation within the desirable time in order to make sure the 250% cropping intensity.

Table 1.   Rules sorting LPWM Expert's outputs for sub-estates E and F.

Flow	Conditions	Output Summary
Design	$P \geq T$	Depth 100mm or more Complete within P
	$P < T$ and $63.5 \leq Dt < 100$	Depth 63.5 – 100mm Complete within P
	$P < T$ and $Dt < 63.5$	Depth < 63.5 by P T needed to supply requirement
	$T > 16.0$ and $Dt < 63.5$	Pumping needed in few tertiary blocks
Less than design discharge	$T \leq 14.0$ and $Dt \geq 63.5$	Depth ≥ 63.5mm Complete within 14 days
	$T \leq 14.0$ and $Dt < 63.5$	No such case
	$T > 14.0$ and $Dt \geq 63.5$	Depth ≥ 63.5mm Complete within 14 days
	$T > 14.0$ and $Dt < 63.5$ Depth at Control $D \geq 2.069$	Pumping needed in few tertiary blocks
	$T > 14.0$ and $Dt < 63.5$ Depth at Control $D < 2.069$	Pumping needed in few tertiary blocks in Sub-estate E Postpone land preparation in few tertiary block in sub-estate F

P = Preferred duration to complete water management during land preparation (days);
T = Time (days) calculated by the mathematical relationships incorporated to ES;
Dt = Average standing depth of water in field plots

The land preparation water management outputs generated by the ES for sub-estates E and F follows the simple rules shown in Table 1 to display the final results for the users action. The outputs are always supported by graphical representations of the specific secondary or tertiary blocks concerned. When the pumping or land preparation postponement is proposed, the tertiary blocks in which the operation to be practiced are shown together with the amounts to be supplied by pumping. Fig. 4 shows a sample output from sub-estate E. The main frame shows the output while the sub-frame is loaded with the project area where pumping is necessary.

The land preparation water requirement is supplied in two steps in Sub-estate G. The first step supplies the soaking requirement while the second step supplies the standing water depth. The standing depth is supplied in a single day or in two days by operating a single tertiary canal within a secondary block. The soaking requirement needs to be supplied within 14 days. In sub-estate G, the soaking could be completed within this duration even the water level in canals decrease. Few blocks face problems but the amount of water that could be saved from other blocks are used in these problematic blocks. The ES is capable of showing all these differences among blocks for a problematic situation.
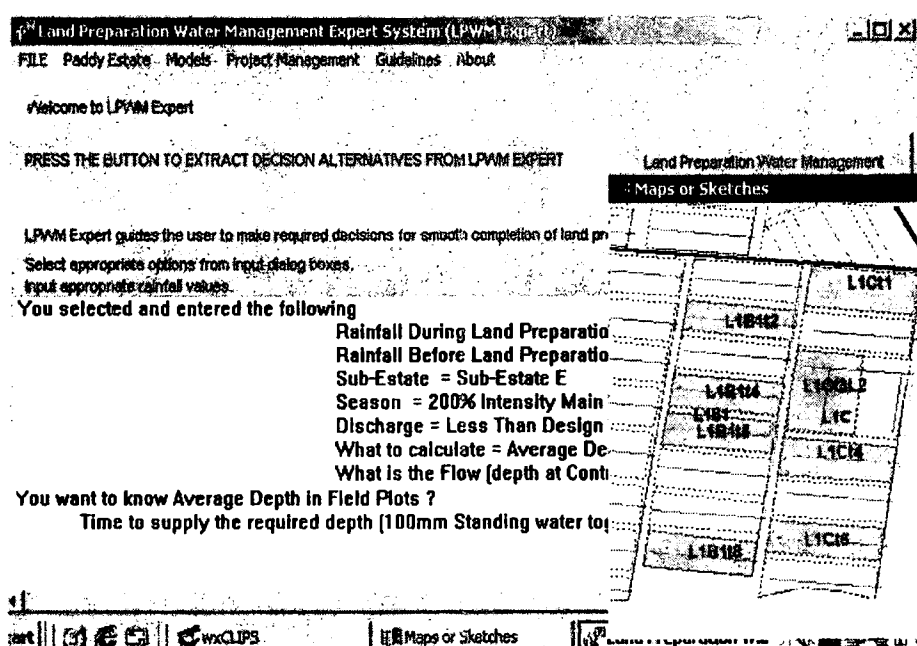
Fig 4.   LPWM Expert output.

Verification of an ES needs checking accuracy, completeness and consistency of developed software. This process starts from the beginning of programming. Logical verification of the knowledge base is important for proper functioning of the system where logical consistence and logical completeness is checked. Verification therefore involved removal of syntax errors, incompleteness and inconsistency in system rules and reasoning. Each rule added to LPWM Expert was checked for the consistency and debugged using wxCLIPS debugging facility. The same facility is used throughout the programming to check syntax errors, omissions of function declarations and missing variables. The inputs through keyboard are checked for the consistency by syntax incorporated to the program itself.

The validation process of the LPWM Expert started from the knowledge generation process. Generated knowledge through modeling and other means are checked with domain experts to make sure the knowledge is acceptable to the final user. The knowledge generated after coding each rule to the ES was checked with the pseudocodes and rechecked with the domain experts. Each and every rule firing was also checked for its appropriateness for the options selected. These two procedures, validation and verification, ensures the systems acceptability and accuracy for land preparation water management. The LPWM Expert is efficient and effective in proposing different management decision-alternatives.

CONCLUSIONS

The process of developing an ES for water management during land preparation for an intensively cultivated mechanized paddy estate is outlined. The relevant experiences available among domain experts were converted to rules in the knowledge base. Models were applied to generate additional knowledge for possible combination of scenarios. The extracted knowledge was verified by the domain experts prior to be added to the ES. The knowledge base, inference

mechanism and the user interface, which are designed using wxCLIPS, provides efficient and effective environment for interactive decision-making by the users. The ES, LPWM Expert, is capable of guiding the user in making required decisions to smoothly complete the water management during land preparation process in the paddy estate even without an expert. The ES provides the outputs or decision alternatives in a text format and supported by graphics so that the decision-making becomes more attractive and efficient. The ES also guides the user during the process of decision-making by providing intermittent results, which are guidelines, current practices or warnings. The Seberang Perak paddy estate management can replace its traditional way of decision-making with LPWM Expert during the land preparation process.

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